A Study of Landscape Ecology of Feng Shui Woodlands in Hong Kong, Using High Resolution IKONOS Imagery and GIS

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Abstract

Feng Shui woodlands are small patches of woodlands, associated with villages and scattered throughout the New Territories. They are often crescent-shaped and lying protectively around the rear of villages. The woodlands have been well preserved by the villagers due to Feng Shui reason. Thus, the woodlands are of high historical and cultural values due to the long time interaction between the woodlands and the villagers.

Feng Shui woodlands consist of native forest trees as they have been well preserved. They were evidenced that they are ecologically rich and possess distinct and unique species. More than 560 species were identified by Chu (1998) in 112 woodlands throughout the territories.

An IKONOS multispectral image covering the Northeastern part of New Territories is acquired in this study. A supervised classification is performed on the geometrically and radiometrically corrected image to produce a land cover map, using the Maximum Likelihood Classification Algorithm. Totally, 53 patches of Feng Shui woodlands are extracted based on the classification result for further analysis.

The landscape ecology of Feng Shui woodlands is evaluated in terms of landscape metrics and surrounding landuse composition. Patch level of metrics, such as area and perimeter, are calculated by the program, FRAGSTAT. The largest patch identified is the Feng Shui woodland behind Ho Sheung Heung, over 6.9 hectares. The landuse composition in Feng Shui woodlands' neighbourhood is estimated. Built-up area and vegetation are both dominated types of landuses. A GIS database is constructed to store, display and further analyze this data.

Factor analysis is performed to reduce data dimensions in landscape metrics and landuse composition. The factors extracted are used as inputs in correlation and clustering analysis. No significant correlation exists between physical patch characteristics of Feng Shui woodlands and their surrounding landuses, which means physical characteristics of Feng Shui woodlands are insensitive to their surrounding landuses. A total of three clusters of Feng Shui woodlands with various landscape ecological characteristics are formed. Among them, Cluster 1 woodlands have low landscape ecological value since they are small in size and relatively isolated from other woodlands. Woodlands of Clusters 2 are of high landscape ecological value due to their medium size, their green landscape and many Feng Shui woodlands nearby. Cluster 3 woodlands are large and complex and are considered as most ecologically important.

論文摘要

風水林散佈於新界多條古老村落，大多面積細小，形狀多爲馬蹄型。它們一般位於村莊後方，由於村民相信風水林與村落之風水有關而加以保護，使它們甚少受到外界破壞。故此，風水林與村民之間的互動使其衍生極高歷史及文化價值。風水林多由原始森林樹木所構成，林內物種豐富，並有獨特的樹種。據 Chu (1998) 研究所示，全港一百一十二片風水林內共發現超過五百六十個樹種。

本研究採用 IKONOS 多光譜衛星圖像來擷取位於新界東北部風水林的位置。這圖像經幾何與光學反射糾正後，會利用監督分類 (MLC) 來擬備土地覆蓋分佈圖，在研究區域內共有五十三片風水林被擷取作爲進一步研究之用。

風水林之景觀生態學的研究會透過計算景觀指數及周圍環境土地利用之成份，例如利用 FRAGSTAT 程式計算每片林地的面積和周界。計算後發現河上鄉風水林的面積最大，超過 6.9 公頃。在周圍環境土地利用成份方面，以已興建土地和植被爲主。有關之研究數據會製成地理信息系統數據庫，以用作儲存、顯示及其後研究之用。

本研究以因素分析分別抽取已計算之景觀指數及周圍環境土地利用之因素，有關因素會被輸入作相關分析及集群分析。相關分析顯示出風水林的物理結構與周圍環境之土地利用並無顯著關係，這說明了風水林不受到周圍土地利用影響。集群分析把五十三片風水林歸類為三個集群，它們各具有不同的景觀生態特徵。三個集群當中：第一集群的風水林因面積較少及與其他風水林距離較遠，故其景觀生態價值較低；第二集群的風水林之面積為中等，周圍環境的土地利用以植被為主，再加上鄰近其他風水林，故其景觀生態價值較其他兩個集群為高；第三集群的風水林因面積最大及形狀較複雜，故此集群樹林的生態價值為最高。

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Chapter 1 Introduction

This study aims at investigating the landscape ecology of Feng Shui woodlands and constructing a geographical information system (GIS) database for Feng Shui woodlands in Northeast New Territories. The evaluated landscape ecology of Feng Shui woodlands fills in the knowledge gap of the landscape value of Feng Shui woodlands. Also, constructing a GIS database for Feng Shui woodlands is essential for any other further studies on the woodlands as well as provides a convenient means to incorporate a huge amount of data of various kinds for displaying, storing and managing purposes.

1.1 Background to the Study

1.1.1 Feng Shui Woodlands

Feng Shui woodland is a unique feature in the countryside of South China. These woodlands are often of small area, crescent shape and lying behind the villages (Catt, 1986). In Hong Kong, they are scattered throughout New Territories. These woodlands have been preserved and protected by villagers for as long as 400 years (Thrower, 1975; Dudgeon & Corlett, 1994) due to Feng Shui reasons, and they essentially consist of native forest trees

(Catt, 1986). Their ecological importance was evidenced in many studies (Thrower, 1975, Webb, 1996, Chu, 1998).

Apart from preserving the woodland, a variety of trees, such as *Aquilaria sinensis, Euphoria longan*, *Litchi chinensis* and *Bambusa spp.*, had also been planted in the woodland. Feng Shui woodland is thus described as an "enriched woodland" (Thrower, 1975; Catt, 1986). Many studies (Thrower, 1975; Webb, 1996; Chu, 1998) certified the properties of ecological diverse and rich of Feng Shui woodlands. The characteristic of very few common species to Feng Shui woodlands (Thrower, 1975) suggests that every patch of Feng Shui woodlands is unique and distinct.

More than a quarter of Feng Shui woodlands (89 out of 337) found by Webb (1996) are located at North New Territories, where there has been undergoing rapid change or development in the last two decades. In order to deal with the ever-increasing population in Hong Kong, North New Territories has been planned to accommodate a total population of 0.34 million in 2011 (Planning Department and Territory Development Department, 2003a & 2003b). Also, a total of 162 hectares of land will be reserved for industrial and open storage uses. In addition to the extensive railway and other infrastructure development, North New Territories thus will be under great development pressure, especially the traditional villages and the woodlands behind them.

The cultural and traditional value as well as ecological importance of Feng Shui woodlands make them eligible for ecotourism or green tourism. Feng Shui woodland is a kind of heritage resources which provides a means of interpreting social, cultural and economic changes and human understanding in the past (Planning Department & Environment Resources Management, 2000). In addition, green vegetation attracts visitors most among other landscapes (Atauri *et al.*, 2000). Conducting ecotourism in Feng Shui woodlands raises public awareness of protecting the woodlands against developmental activities.

Many studies on Feng Shui woodlands, mainly in ecological aspects, were conducted (Thrower, 1975, Webb, 1996, Chu, 1998) and a large amount of data, for example, species compositions, was generated. How to manage such a large amount of data structurally becomes a key question.

Constructing a GIS database thus becomes necessary in order to store, manage and display the data for further uses and studies as well as help further analyze the data, for instance, the ability of overlaying various layers such as roads, buildings and industrial uses, on the woodland layer makes interpretation of the interactions of these layers possible.

1.1.2 Landscape Ecology

Landscape is referred as "*a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout*" (Forman & Gordon, 1986, p11). Landscape ecology aims at studying the interaction between spatial pattern and ecological processes, which is the study on the causes and the consequences of spatial heterogeneity across a range of scales. It specifically focuses on three characteristics of the landscape, 1) Structure; 2) Function; and 3) Change (Forman & Gordon, 1986).

Landscape ecology approach is widely applied to study our landscape and related ecological processes. With digital remotely sensed imagery, meaningful biophysical and spectral information can be extracted from the imagery for further interpretation. For instance, vegetation indices are used as indicators of relative abundance and activity of green vegetation (Jensen, 2000). Many landscape metrics have thus been developed to quantify the landscape pattern which in turn assists making inference on ecological processes of interest, such as predicting species dispersal by habitat fragmentation pattern (Schumaker, 1996).

Studying landscape ecology of Feng Shui woodlands by using remote sensing techniques provide a holistic understanding of Feng Shui woodlands and their surroundings over a large area. In this study, the spatial distribution of Feng Shui woodlands in Northeast New Territories is delineated from a digital IKONOS image, from which the number of patches and location of Feng Shui woodlands are determined. Is there any clumpy pattern or other patterns observed within the study area? Moreover, the landscape of Feng Shui woodlands is evaluated in terms of individual patch characteristics and landuse composition. What are the size and the shape of the Feng Shui woodlands? Are they consistent in size and shape? What is the landuse composition of Feng Shui woodlands' neighbourhood? Is there any interaction or relationship between the surrounding landuse composition and the physical characteristics of Feng Shui woodlands? These answers give us an insight into the landscape ecology of Feng Shui woodlands.

1.2 Objectives of the Study

This study is to answer the questions stated above and specifically, focus on the following issues,

I. To investigate the feasibility of using high resolution imagery, IKONOS, to find out the number, location and spatial distribution of Feng Shui woodland patches and woodland patches of similar size and shape in Northeast New Territories.

II. To determine the patch characteristics, such as area, perimeter and shape, and the neighbourhood landuse composition of extracted woodland patches.

III. To investigate the relationship between Feng Shui woodlands' patch characteristics and their surrounding landuse composition.

IV. To evaluate the landscape ecological value of Feng Shui woodlands according to their patch characteristics and landuse composition.

1.3 Significance of the study

Investigating landscape ecology of Feng Shui woodlands by adopting remote sensing and GIS techniques gives us a holistic view on regional distribution of Feng Shui woodlands as well as landuse interaction surrounding Feng Shui woodlands. In addition, the measured landscape characteristic of the woodlands patch and the estimated landuse composition around that Feng Shui woodland may assist judging the landscape value of that Feng Shui woodland. This value may be in turn used as a measure of estimating ecotourism potential of the Feng Shui woodland.

Much effort was put on studying the ecological aspects of the Feng Shui woodlands (Thrower, 1975; Webb, 1996; Chu, 1998). Construction of a GIS database for Feng Shui woodlands is the first step of any other further investigations on the woodlands. The GIS database constructed would facilitate displaying, storing and managing of such a huge amount of data and offer easy access of this set of data in a user-friendly and attractive way. Also, the ability of overlaying various layers on the woodland layer makes interpretation of the interactions of these layers possible.

An IKONOS imagery would be processed to delineate the Feng Shui woodlands in this study instead of using aerial photographs as the previous studies did because the satellite image possesses a number of advantages over aerial photographs. Firstly, it covers a large areal extent (about 12 km X 12 km), which would be suitable for landscape analysis, while a number of aerial photographs would be needed for the same areal extent if aerial photographs were used in this study, which would cause inconvenience in unifying the data sets.

Secondly, satellite imagery usually possesses an extended spectral range. For example, IKONOS has four spectral bands, i.e. red, green, blue and infrared. While for aerial photographs, they only have three spectral bands, i.e. red, green and blue for true colour aerial photograph. The extended spectral bands in satellite imagery would provide extended data input for classification, which may result in a better classification. It is especially true for vegetation study when infrared is incorporated into classification.

The much higher altitude of the remote sensor taking satellite imagery, compared with that of the sensor taking aerial photographs, would be capable of taking a nearly perfectly vertical orientation imagery. This would result in less terrain distortion and more precise pointing direction. Moreover, the digital satellite imagery is readily overlaid with different digital GIS layers, such as vectors of road, building and so on, for analysis, which assists delineating of Feng Shui woodland patches more accurately. These advantages, in addition to the high spatial resolution (4 m X 4 m) of IKONOS imagery, make using IKONOS more feasible and suitable for landscape ecological study than using aerial photographs.

1.4 Definitions

For the purpose of this study, Feng Shui woodlands are defined as follows:

a. those large trees or woodlands in close proximity to indigenous, traditional villages of the New Territories;

b. those large trees or woodlands in close relation to the villages, such as those located at or near the shrines or other features associated with the villages; or

c. those woodlands of similar shape and size compared with proven examples, which may be associated with abandoned or demolished villages.

The village locations are identified by using a set of geo-referenced village polygons (G1000) provided by the Lands Department, Hong Kong Special Administrative Region, as well as from 1:20000 topographic maps. Since, apart from a woodland grove lying behind the village, there may be some individual Feng Shui trees grown around the village, a term “cardinal patch” is used in this study, which is defined as the largest integral patch of Feng Shui woodland. In assessing the landscape characteristics of Feng Shui woodland, the cardinal patch is assessed instead and representing associated Feng Shui woodlands.

1.5 Organization of the Thesis

This thesis begins with this introductory chapter and is followed by Chapter 2, literature review in which landscape ecology and Feng Shui woodlands are reviewed. Specifically, the applications of landscape ecology and landscape metrics are discussed. For Feng Shui woodlands, the physical characteristics, the ecological importance and the functions of Feng Shui woodlands are further elaborated.

Methodological framework of this study is discussed in Chapter 3. This chapter starts with study site description and is followed by identification of Feng Shui woodlands. The landscape ecology of Feng Shui woodlands is assessed by means of extracting landscape metrics and estimating surrounding landuse composition. A GIS database is constructed to store and analyze these results. Finally, evaluation of landscape ecology is performed by correlation and clustering analysis.

Number and spatial distribution of identified woodlands are presented in Chapter 4. Patch characteristics, such as area and shape, of Feng Shui woodlands in terms of patch level landscape metrics are also discussed in this chapter. Moreover, in order to reduce the data dimensions of calculated metrics, factor analysis is performed and the results are elaborated.

The landuse composition in Feng Shui woodlands' neighbourhood and the change of landuse composition in the woodlands' surroundings are elaborated in Chapter 5. Factor analysis is also performed to reduce the data dimensions and extracted factors are also described. Correlation analysis is performed to investigate any relationship between patch characteristics of Feng Shui woodlands and their surrounding landuses, and clustering provides a classification of Feng Shui woodlands according to woodland patch characteristics and landuse composition. Lastly, the GIS database constructed is described in this chapter.

This thesis ends with a concluding chapter, Chapter 6, in which the general approach is reviewed. The landscape ecological value of Feng Shui woodlands is summarized and finally, some limitations of this study are discussed.

Chapter 2 Literature Review

2.1 Landscape Ecology

2.1.1 Definition

Landscape can be defined as" *a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout.*"(Forman & Gordon, 1986, p11). Urban *et al.* (1987) considered landscape as a mosaic of patches, the components of pattern. The term, ecotope, is the smallest holistic land unit characterized by homogeneity of at least one land attribute of the geosphere (Naveh & Lieberman, 1983, p5), was promoted by C.Troll since 1945 to represent the smallest unit of the landscape (Troll, 1971). Another term, tessera, was defined by Forman and Gordon (1986) as the smallest homogeneous unit visible at the spatial scale of a landscape. The landscape structure was recognized at two levels by Ruzicka *et al.* (1978). Firstly, "Landscape components" are the units within a landscape determined by the physical or natural environment; Secondly, the level superimposed on it is "Landscape elements", which are mainly determined by human influences. Forman and Gordon (1986, p12) simply refer "Landscape elements" as the basic, relatively homogeneous, ecological elements or units, whether they are of natural or human origin. Some of them may be considered as ecosystems and they are usually identifiable in aerial photography, often ranging from 10 m to 1 km or more in width (Forman and Gordon, 1986, p12). Wiens (2002) summarized the definitions of landscape into two characteristics, firstly, landscapes are composed of multiple elements (or patches), and secondly, the variety of these elements creates heterogeneity within an area.

Landscape ecology deals with the causes and consequences of the spatial composition and configuration of landscape mosaics and is closely linked to biological conservation (Weins, 2002). A wider scope can be found in the following definition: "*Landscape ecology focuses explicitly upon spatial patterns. Specifically, landscape ecology considers the development and dynamics of spatial heterogeneity, spatial and temporal interactions and exchanges across heterogeneous landscape, influences of spatial heterogeneity on biotic and abiotic processes, and management of spatial heterogeneity.*" (Risser *et al.*, 1984)

Similar idea about landscape ecology can also be found from Forman and Gordon (1986). They stated out three characteristics of the landscape that landscape ecology focuses on: 1) structure, that is the spatial relationships among the distinctive ecosystems or "elements" present; 2) function, the interactions among the spatial elements, which is the flow of energy, materials and species among the component ecosystem; 3) change, the alteration in the structure and function of the ecological mosaic over time."

Landscape ecology should embrace both the spatial or the horizontal approach and the biological-ecological vertical approach (Troll, 1971). Forman and Gordon (1986) stated that landscape ecology should be regarded as a multidisciplinary science, which combines the spatial approach of the geographer with the functional approach of the ecologist. Landscape should be regarded as a holistic system, which represents a part of "Total Human Ecosystem" in landscape analysis (Bastian, 2001). The holistic approach suggests that, in landscape analysis, apart from only investigating the landscape of interest itself, the interaction among the natural, socio-cultural and economic systems, especially the human-nature relations, should also be considered in landscape study so as to fully understand its totality, rather than the sum of its parts, of the landscape. Thus, landscape ecology can be viewed as a human-related science (Naveh & Lieberman, 1983).

In addition, any landscape studies should involve at least three hierarchical levels. A hierarchy is defined as a system of interconnections wherein the higher levels constrain the lower levels and within this hierarchical system, the levels are distinguished by differences in the rates, or frequencies or their characteristics processes (Turner *et al.*, 2001). The focal level or the level under investigation is constrained and controlled by the upper level and is explained by the level below (O'Neill *et al.*, 1986). This hierarchy theory implies that the landscape of interest should be looked as a whole but not simplified it to specific landscape subsets and assists researchers to define scale in their studies.

2.1.2 Applications

There have been many researches investigating on landscape ecology using remotely sensed techniques in these past two decades (e.g. Turner & Ruscher, 1988; Turner, 1990; Schumaker, 1996; Tinker *et al.*, 1998; Griffiths *et al.*, 2000; Fuller, 2001). Extensive effort was put on characterizing the landscape pattern (Griffiths *et al.*, 2000; Liu & Cameron; 2001), studying and monitoring the landscape change or dynamism (Turner, 1990; Pachepsky & Ritchie, 1998; Taylor *et al.*, 2000; Walsh *et al.*, 2001; Crews-Meyer, 2002), and evaluating the impact of human activities on natural resources (Tinker *et al.*, 1998; Fuller, 2001; Young & Jarvis, 2001).

The increasing prevalence of research on landscape ecology may be mainly due to an increasing recognition of the importance of environment, resource management as well as the interactive relationship between landscape pattern and ecological processes. In addition, digital remotely sensed data is one main type of the data used in landscape analysis (Dunn *et al.*, 1991). It possesses a number of advantages that stimulate the development of landscape research. Remote sensing is defined as "*the art and science of obtaining information about an object without being in direct physical contact with the object*" (Jensen, 2000). Therefore, apart from collecting information from object without possessing a risk of destructing the object, remotely sensed data is, firstly, relatively cost-effective when compared with manual collection of data of the same areal extent. Secondly, the temporally frequent, spatially extensively covered and spectrally detailed data facilitates landscape studies of various scales or at multi-scale spatially and temporally. Thirdly, the high spatial resolution data (5-meter and 1-meter for the panchromatic SPOT 5 and IKONOS imageries respectively) gives us more reliable land cover information of the landscape and last but not least, the digital imagery enables the users to access and process the data repeatedly. (Griffiths & Mather, 2000). Moreover, it is more prevalent and convenient to incorporate the remotely sensed land cover data with Geographical Information System (GIS) in landscape analysis (Schumaker, 1996; Luque, 2000; Taylor *et al.*, 2000; Fuller, 2001; Liu & Cameron, 2001; Kelly & Meentemeyer, 2002). Integration with GIS provides a means to store and manage the data in a structural and convenient way as well as to further analyze the data (e.g. proximity analysis, buffering, etc.).

2.1.3 Landscape Metrics

Landscape metrics or indicators have been developed to quantify the landscape pattern. They are a useful tool to quantify landscape structure in terms of landscape configuration and landscape composition (Haines-Young & Chopping, 1996). Composition is a non-spatially-explicit characteristic such as land cover proportion, richness or dominance, while configuration relates to spatially-explicit characteristics of land cover types in a landscape, such as patch geometry and spatial distribution of patches (Leitão & Ahern, 2002). Landscape structure must be identified and quantified in meaningful ways in order to understand the interactions between landscape patterns and ecological processes (Turner, 1989). For instance, metrics of patch richness (PR) or dominance may give indication in the degree of simplification or reduction of diversity of studied landscape. Landscape pattern is actually the spatial distribution of dominated vegetation types. The dominant vegetation establishes the resource base for the rest of ecosystem and its pattern affects the spatial patterns of all components of the system (Turner *et al.*, 2001). Landscape pattern can result from abiotic causes, such as climatic variability, and biotic causes. Interaction among organisms, such as competition and predation, may also lead to a change in landscape pattern. On the other hand, landscape pattern may in turn affect dispersal pattern of organisms, redistribution of nutrients or spread of a natural disturbance.

A core set of landscape metrics was proposed by Leitão and Ahern (2002), which includes nine basic metrics, for sustainable landscape planning. They can be classified into landscape composition and configuration metrics. For landscape composition metrics, they are, 1) Patch richness (PR) and class area proportion (CAP); 2) Patch number (PN) and patch density (PD); 3) Mean patch size (MPS). For the others, they belong to landscape configuration metrics. They are, 4) Patch perimeter-to-area ratio; 5) Total edge contrast index (TECI); 6) Radius of gyration and correlation length; 7) Mean nearest neighbour distance (MNND); 8) Mean proximity index; and 9) Contagion. This core set of metrics aims at providing the smallest set of tools possible to describe landscapes (Leitão & Ahern, 2002).

Riitters *et al.* (1995) also narrowed down 55 metrics to 6 metrics, including 1) Dominance, 2) Contagion, 3) Fractal dimension from Perimeter to Area Ratio, 4) Average Patch Perimeter/Area Ratio, 5) Average Patch Perimeter/Area Ratio Orthogonally Adjusted, and 6) Number of classes (Riitters *et al.*, 1995). Among them, Dominance, Contagion and Fractal Dimension are the metrics suggested by O'Neill *et al.* (1997), which can be used to monitor the quality of ecosystem within the environment.

Dominance (O'Neill *et al.*, 1988), D, is defined as "the degree to which one or a few land cover types predominate the landscape in terms of proportion" (Forman and Gordon, 1986). Its equation is given by:

$$D = 1 - \frac{\sum(-P_K \ln P_K)}{\ln(s)} \qquad \text{eq. 2.1}$$

where $0<P_k<1$ is the proportion of land cover type k, and s is the total number of land cover types present in the landscape. Its value is between 0 and 1, with a high value indicating dominance by one or a few land cover types and a low value showing that the land cover types are present in nearly equal proportions. It is closely related to the Diversity metric, from which the Dominance metric was derived. So, its value can also give us an idea about the degree of evenness of various land cover types.

Contagion (O'Neill *et al.*, 1988), C, is used to measure the tendency of land covers to cluster or clump into a few large patches (Wickham *et al.*, 1996). It was derived from the Shannon evenness metric for edge types by O'Neill *et al.* (1988). The equation is given by:

$$C = \frac{\left[1 + \sum_{i=1}^{s}\sum_{j=1}^{s} P_{ij} \ln P_{ij}\right]}{2\ln(s)} \qquad \text{eq. 3.2}$$

where P_{ij}= the probability that two randomly chosen adjacent pixels belong to land cover types i and j, and s is the number of land cover types on the landscape. The value of this metric is between zero to one, again, with a high value indicating generally clumped patterns of land-cover types across the landscape and a low value indicating a landscape with a dispersed pattern of cover types. Obviously, it can be used to measure the degree of fragmentation (e.g., Schumaker, 1996). A landscape with high contagion would be one with low fragmentation while a landscape with low contagion would be one with high fragmentation.

Although Contagion is widely used by researchers, as suggested by Frohn (1998), it is adversely affected by 1) measurement resolution; 2) raster orientation; and 3) varying the number of land-cover classes. Thus, Frohn suggested an improved metric, Patch-Per-Unit Area, PPU and its equation is given by:

$$PPU = \frac{m}{(n \times \lambda)} \qquad \text{eq. 3.3}$$

where m is the total number of patches, n is the total number of pixels in the study area, and λ is called scaling constant which equals to the area of the pixel. It is expressed in any unit such as m^2 or ha. PPU is low when the landscape is not fragmented while a high value indicates the landscape more fragmented. It is expected that it is less sensitive to the spatial resolution and more sensitive to landscape pattern than Contagion.

Fractal Dimension (Mandelbrot, 1977), FD, measures the patch shape complexity based on the perimeter-to-area ratio of the patch. This complexity of shape is reflected in the speed with which apparent length changes as measurement scale changes (Sugihara & May, 1990). The equation is given by:

$$FD = \frac{2 \times (\ln P - \ln k)}{\ln A} \qquad \text{eq. 3.4}$$

where P and A are the perimeter and the area of the patch respectively, and k is the constant of proportionality. The value of Fractal Dimension is between 1 and 2. In general, complex patches are those with greater perimeter-to-area ratios (close to 2) while simple patches are those with lower perimeter-to-area ratio (close to 1). It can be used to indicate the extent of human disturbance on the landscape because human creates simple shapes while the nature generates complex configurations (O'Neill *et al.*, 1997).

Fractal Dimension possesses a list of potential problems (Frohn, 1998) such as 1) problems with perimeter to area regression; 2) problems with the raster data structure; and 3) effects of measurement resolution. An alternative improved metric called Square-Pixel, SqP, was suggested by Frohn (1998) to measure the patch shape complexity by considering the perimeter area relationship for raster data structures and normalize the ratio of perimeter and area to a value between 0 (for squares) and 1 (maximum perimeter, edge, deviation from that of a perfect square). SqP is given as:

$$SqP = 1 - \left(\frac{4 \times A^{1/2}}{P} \right) \qquad \text{eq. 3.5}$$

where A is the total area of all pixels and P is the total perimeter of all pixels in the study area. SqP is unitless and predictable with measurement resolution and it does not assume a power relationship between perimeter and area while Fractal Dimension does. It is more effective in measuring the patch shape complexity for landscapes which do not exhibit statistical fractal geometry.

2.1.4 Applications of Landscape Metrics

Landscape metrics have been widely used to quantify the landscape pattern, which assist making inference on the ecological processes in interest (Schumaker, 1996; Griffiths *et al.*, 2000; Luque, 2000; Fuller; 2001). This kind of studies can give us an economic and broad-scale understanding of our environment such as the landscape diversity of the environment and the degree of fragmentation. The acquired ecological knowledge is essential when planning for sustainability (Leitão & Ahern, 2002).

Habitat fragmentation is one of the phenomena driven by anthropogenic activity (Young & Jarvis, 2001) and much effort was put on measuring fragmentation pattern on landscape (Fuller, 2001; Young & Jarvis, 2001) and its ecological consequences (Collinge, 1996; Gardner *et al.*, 1993). Jaeger (2000) modified from Forman's concept (1995) and identified 6 phases of fragmentation process. They are perforation, incision, dissection, dissipation, shrinkage and attrition, any of which can occur simultaneously. The distinction of these phases is useful in quantitative measurement of habitation fragmentation, which in turn help analyse and report fragmentation trends over time.

Habitat fragmentation, especially those driven by anthropogenic activity, does not only directly cause habitat loss, but also indirectly reduce the inter-patch dispersal of the population inside. Thus, when the degree of fragmentation increases, the patch remained becomes more and more isolated (Schumaker, 1996; McComb, 1999). This can cause decline in species population ultimately (Schumaker, 1996; Jaeger, 2000). Some landscape metrics are frequently used to estimate the habitat connectivity, the converse of habitat fragmentation, which are used to quantify the hindrance of dispersal process caused by habitat fragmentation, in many landscape analysis.

To testify whether these landscape metrics can truly reflect the real situation, Schumaker (1996) looked for correlations between nine common landscape metrics, including, Number of Patches, Sum of Patch Area, Sum of Core Area, Sum Nearest Neighbours, Contagion, Fractal Dimension, Shape Index and Perimeter-to-Area Ratio, and the simulated dispersal processes conducted by using GIS data. Although the results showed weak correlations between the above metrics and simulated dispersal process and a new index, Patch Cohesion was invented in this study and it was found to have a better correlation with dispersal process than the others.

Schumaker (1996) also pointed out that during developing and testing landscape metrics, the use of computer-generated or simulated landscapes could both over-estimate the value of poor predictors of ecological quality and diminish the power of useful indices.

Fuller (2001) determined the spatial and temporal forest fragmentation pattern in eleven watersheds of Loudoun County in terms of landscape metrics for 1973, 1987 and 1999, and correlated the four estimated metrics, Fragmentation Index, Center versus Neighbours, Perimeter-to-Area (P/A) ratio and Square Pixel, with the thermal infrared radiance to investigate the impact of urban sprawl. This study was based on the fact that urbanization is likely to result in forest fragmentation and the new land cover surfaces generally possess low thermal inertia relative to vegetated surfaces, which increase local ambient air temperature. This increased temperature can be reflected in the increased thermal infrared radiance.

The results found that fragmentation of forest cover increased from 1987 to 1999 and the Perimeter-to-Area ratio showed a strong positive relationship with the mean radiance of forest patches. This means that the amount of forest edge is related to mean surface temperature and the P/A ratio conveys important biophysical information in studying forest fragmentation at a broad scale. In addition, a negative linear relationship between the distance from major roads and thermal infrared radiance of forest pixels was found, which indicates that advection of warm air from those major roads may influence the surface temperature of forest pixels.

Some points should be noted in applying landscape metrics in these studies. Firstly, since the description of landscape pattern usually requires more than one landscape metric, how many and which metrics are going to be used become a key question before any studies are conducted. In addition, landscape metrics are frequently strongly correlated with each other (Leitão & Ahern, 2002), that means reporting various inter-related metrics yields redundant information which may make interpretation more difficult. From the study of Riitters *et al.* (1995), among 55 different landscape metrics, redundancy exists among them and 6 independent factors were identified by factor analysis. Six metrics representing these factors respectively are stated earlier in p.17. (Riitters *et al.*, 1995). Therefore, this redundancy should be minimized during selection of the metrics in order to make an effective and meaningful interpretation.

Secondly, the meaning and constraints of the metrics should be well understood, as recommended by Haines-Young and Chopping (1996), in order to make a correct interpretation of the metrics and to avoid misuse of the metrics. In addition, some metrics are sensitive to various factors such as spatial map extent, pixel size and so on. Caution should be made during comparison sets of metrics from imagery data of different remotely sensors. How to select appropriate metrics for landscape analysis would depend on the scope of study, i.e. the ecological processes of focus, as well as the implications and limitations of the selected metrics.

2.1.5 Sensitivity of the Metrics

Calculation of landscape metrics from land cover data is becoming increasingly common in various environmental studies (O'Neill *et al.*, 1997; Pachepsky & Ritchie, 1998; Griffiths *et al.*, 2000; Luque, 2000, Walsh *et al.*, 2001). However, owing to their inborn nature, they are expected to be affected by the characteristics of remotely sensed imagery, such as spatial resolution and map extent. These problems make analysis of the landscape pattern and comparison between sets of data from various remote sensors more complicated or sometimes, inappropriate.

In order to alleviate such kind of problems, much effort has been put on investigating the sensitivity of the metrics towards various factors such as landscape pattern variation (Frohn, 1998), land-cover misclassification (Wickham *et al.*, 1997), map spatial extent (Saura & Martinez-Millan, 2001), spatial resolution and pixel size (Wickham & Riitters, 1995; Frohn, 1998). These studies in turn simulate the development of improved metrics such as PPU and SqP (Frohn, 1998) stated above although thorough examinations are needed to verify these improved metrics.

Since remotely sensed data from various sensors are different in spatial resolution (e.g., 1-meter, 5-meter and 15-meter for panchromatic IKONOS, SPOT 5 and LANDSAT-TM respectively) and coverage, the estimated landscape metrics are expected to be sensitive towards both map extent and spatial resolution, or scale. Scale of spatial data is an important problem and should be considered in comparing land-cover patterns (Saura & Martinez-Millan, 2001). Scale comprises of grain and map extent (O'Neill *et al.*, 1996). Grain is the spatial resolution of the data and is defined by pixel size while map spatial extent is the total area of the map being considered (Saura & Martinez-Millan, 2001). Grain (Wickham & Riitters, 1995) and map extent (Saura & Martinez-Millan, 2001) were both shown to be influencing the values of spatial pattern metrics

Wickham & Riitters (1995) investigated the sensitivity of Shannon and Simpson Cover Type Diversity metrics, Shannon and Simpson Evenness metrics, Shannon and Simpson Evenness metrics for edge types and Contagion towards pixel size. The results showed that the effect of pixel size on Edge Type Evenness metrics and Contagion is significant, although the effect is small, while that on the other metrics is either insignificant or not important. These results suggests that the values of the landscape metrics tested are predictable in the tested pixel range and given identical classifications for the same area, the estimated landscape metrics should not be dramatically affected by the change in spatial resolution

In Frohn's study, the sensitivity of two commonly used metrics, Contagion and Fractal Dimension were examined against the change of spatial resolution. This study was based on replication of pixels in some simulated landscape patterns. Both Contagion and Fractal Dimension were calculated and compared with his suggested new metrics Patch-Per-Unit

Area and Square-Pixel respectively. The results suggested that both improved metrics are more effective in measuring the desired pattern and are less sensitive to the spatial resolution than the original ones.

The sensitivity of eight common landscape metrics towards map spatial extent was analyzed by Saura and Martinez-Millan (2001). The metrics are Edge Density, Patch Density, Inner Edge Density, Large Patch Index, Patch Cohesion, Mean Shape Index, Area Weighted Mean Shape Index and Perimeter-Area Fractal Dimension. This study is based on simulated landscape pattern which are generated by the Modified Random Clusters method, MRC, (Saura & Martinez-Millan, 2000), which can avoid mixing the effects of class abundance and spatial extent, that were mixed in pervious studies (O'Neill *et al.*, 1996). The simulated landscape patterns are mainly determined by the initial probability controlling the fragmentation of the simulated landscapes.

The results concluded that the sensitivity of the metrics to map extent is highly dependent on the pattern spatial characteristics and tends to increase with aggregation of the landscape. In the case of Inner Edge Density, Patch

Cohesion and Area Weighted Mean Shape Index, they showed decrease with decreasing map extent while for the others such as Patch Density and Mean Shape Index, they showed a reverse trend. Among the metrics under investigation, Edge Density is the most robust metric, which is more suitable for use as a fragmentation index where the map spatial extent is a concern

The sensitivity of three landscape metrics, Average Patch Compaction, APC, Contagion and Fractal Dimension, was investigated towards land cover misclassification and differences in land cover composition (Wickham *et al.*, 1997). It was found that misclassification always resulted in lower values in APC and Contagion and higher value in Fractal Dimension. For the sensitivity towards land cover composition, Contagion showed a negative and significant relationship with land cover composition while APC and fractal dimension did not showed. The result suggests that the differences in land cover composition need to be 5 percent higher than the misclassification rate in order to conclude the difference in landscape metrics are due to the differences in landscape composition but not the misclassification.

2.2 Feng Shui woodlands

2.2.1 General Characteristics

Feng Shui woodland is a unique feature in the countryside of South China, such as in Guangdong and Hong Kong. These woodlands are small in area, scatter around and consist of native forest trees essentially (Catt, 1986). They are often crescent-shaped and lie protectively around the rear of the village (Thrower, 1975; Catt, 1986). In Feng Shui's viewpoint, the village surrounded by Feng Shui woodland of this shape is blessed by Feng Shui since it was believed that the site should be surrounded on three sides of higher land in order to receive protection from inclement weather or enemy (Liu, 1989).

The woodlands are entitled "Feng Shui" (literally, wind-water, and usually translated as geomancy) which is the Chinese belief of an impersonal and supernatural power which can, to some extent, be controlled and directed to people's benefit and fortune while, if misdirected, it may cause misfortune (Thrower, 1975; Catt, 1986). A favorable Feng Shui circumstance of the village can contribute to its prosperity (Liu, 1992). However, in contrary, there were also some cases that villagers violated Feng Shui principles and finally, they met misfortune. In these cases, they might contract fatal disease or died of accident (Huang, 1992).

Feng Shui concerns the balance in nature between buildings and landscape, or the sacred harmony of the built environment (Cheung, 1999). The concept is to adapt the buildings in order to harmonize with the local environment (Liu, 1989). Thus, in China, most villages orientate the buildings to the south to take advantage of the southeasterly wind and sunshine (Liu, 1989; Huang, 1992; Knapp, 1992) and plant Feng Shui woodlands behind the villages so as to block the northern cold wind (Liu, 1989). It creates a pleasant microclimate for the people living in the village as well as for the crops grown there.

The villagers find it important to protect them and keep them away from disturbance due to Feng Shui reasons (Thrower, 1975; Zhuang & Corlett, 1997) as well as their practical functions. It can be seen that some Feng Shui woodlands are over 300 years (Chu & Xing, 1997; Webb, 1996) and some are even over 400 years, such as the ones in Shing Mun Country Park (Dudgeon & Corlett, 1994) and in Wu Kwai Sha Village (Thrower, 1975). Such a long period of preservation (over 300 years) implies that the woodlands, as well as the villages themselves, possess a great historical value as there has been a long time interaction between the indigenous villagers and the woodlands.

Driven by Feng Shui reasons, villagers have retained their Feng Shui woodlands and the trees inside have been strongly prohibited against felling (Webb, 1996). In Sheung Wo Hang Village, no agriculture, fuel cutting, or excavation was permitted on the heavily planted slopes behind the Ancestral Hall in order to protect the Feng Shui woodlands (Hase *et al.*, 1992). With such a little or even no disturbance, they are natural enough. In addition, it was evidenced that trees were planted by their ancestors in the old days (Hammond, 1992) for many reasons. It makes them ecologically rich and diverse with some distinct species which are not found in other forest types (Thrower, 1975; Zhuang & Corlett, 1997). Moreover, these well-preserved Feng Shui woodlands can give us an insight about the possible future direction of plant succession in Hong Kong (Dudgeon and Corlett, 1994). It may be particularly useful for many tree-planters.

2.2.2 Physical and Spatial Characteristics

Feng Shui woodlands are usually in a crescent shape, which curve around both ends of the associated villages like an armchair of the village. Other analogies of Feng Shui woodlands are "crook of the elbow in a curved arm" (Liu, 1989), "clothes" and "cloak" (Webb, 1996). Two "wings" of the woodlands are thought to serve villagers as screening off undesirable views of gaps in the hills in order to discourage the flow of the negative Feng Shui force, *Shaqi* (Hase *et al.*, 1992; Webb, 1996), which is one of the main Feng Shui functions of the woodlands.

In Feng Shui's viewpoint, the most desirable orientation of the villages is the south. Other orientations of the villages in descending desirability are east, west and north respectively (Huang, 1992). In addition, it was believed that a site should be surrounded by higher land on three sides in order to receive protection from inclement winter and enemy (Liu, 1989). Hence the crescent-shape Feng Shui woodlands serves a good Feng Shui setting for the associated villages. An excellent example of village sitting according Feng Shui principles was illustrated by Hammond (1992). Xiqi village in Guangdong faces south and has been set into the south-facing slope of a hill in a way that prominent arms of the hills flank the east and west sides of the village. Moreover, the Feng Shui of this village has even been improved greatly by growing a grove of trees of crescent shape on the slope behind the village. This setting illustrates a good configuration of an azure dragon and a white tiger, which is associated with *yang* and *yin* balance of the village (Fan, 1992). The south-facing village, with grown Feng Shui woodland behind, can take the advantages of, firstly, blocking the north cold wind, receiving sunshine and warm southeasterly wind in winter (Liu, 1989; Hammond, 1992). Secondly, the woodland behind village creates shades to keep the village cool in summer (Hammond, 1992). They are the practical benefits to the villagers brought by the Feng Shui woodlands.

Feng Shui woodlands usually lie behind the villages, so that if a woodland lies on the south side of the village, the village thus faces north, and vice versa. In spite of the Feng Shui benefits brought by the south-facing villages, the villages in Hong Kong do not follow strictly to the Feng Shui principles. From Webb's study, there were total 67 out of 336 woodlands found orienting to the north of the village, i.e. the villages face south, while the largest portion of the woodlands (69 out of 336) were found orienting to the south of the village, thus these villages are north-facing. It seems that, apart from Feng Shui reasons, there are a number of factors, such as local topography, environment and Feng Shui, affecting the position of the Feng Shui woodlands as well as the village orientation (Webb, 1996).

From Webb's study (1996), as listed in Table 2.1, the majority of the Feng Shui woodlands identified were shown to be concentrated in the New Territories (298 out of 337). More than a quarter of the woodlands (26%) are found in the north part of the New Territories, 23% are in Tai Po, 13% are in Yuen Long and 12% are in Sai Kung. The rest are located at Tsuen Wan, Tuen Mun and Shatin those early-developed area.

Table 2.1 Distribution of Feng Shui woodlands by District

Administrative District	No. of Feng Shui Woodlands present
Islands (Lamma & Lantau)	38
North	89
Sai Kung	39
Shatin	24
Tai Po	78
Tsuen Wan	11
Tuen Mun	12
Yuen Long	45
Hong Kong Island	1
Total	337

(source: Webb, 1996)

Such a distribution can be explained by the fact that since Feng Shui woodlands are an integral part of the old villages which are relatively abundant in the rural area of the New Territories, their distribution would be related to the distribution of those villages.

There were a total of 337 patches of Feng Shui woodlands identified by Webb (1996) in his study, with the total size of 703.13 ha and average patch size of 2.08 ha. More that half of the woodlands (53%) identified were found to be smaller than 2 ha and only few patches of woodlands were found to be greater than 9 ha. Such a great difference in size of the woodlands can be explained by the type of terrains where Feng Shui woodlands are located. Since, in the old days, there were demands for farmlands and fuel woods, trees in Feng Shui woodlands locating on flat land would be cut and cleared for the above purposes. Consequently, small size woodlands (<2 ha) were more frequently observed on flat land (81%) than on hill slope (66%) and the woodland size larger than 4.25 ha could only be observed on the hill slopes (Webb, 1996).

2.2.3 *Ecological Importance*

Feng Shui woodlands are described as "enriched woodlands" (Thrower, 1975; Catt, 1986) since apart from preserving the trees inside the woodlands, villagers also planted a variety of trees of various values, such as *Aquilaria sinensis* used for making incense, *Euphoria longan*, *Litchi chinensis* and *Bambusa spp*. planted for the edible and construction purposes. Some other trees would also be planted due to their traditional medicinal and economic value (Thrower, 1975). Their ecological importance was evidenced by a number of studies. Thrower (1975) studied 6 Feng Shui woodlands and recorded 72 species. It was found that the Laurel family (*Cinnamomum*, *Litsea* and *Machilus*) is very well represented in those woodlands. He concluded his study by two observations. They are 1) a remarkably large number of different species recorded in Feng Shui woodlands; and 2) very few common species to the studied woodlands or sporadic occurrence of any single species. These characteristics are similar to those of tropical forest (Thrower, 1975). It implies that every Feng Shui woodland is distinct and unique in terms of plant species composition.

Webb (1996) compared the identified woodlands with that of 50 years ago and studied the botanical characteristics of Feng Shui woodlands. He identified 335 traditional villages which have recognizable Feng Shui woodland immediately adjacent to the village. There were a total of 145 species in 51 families recorded. These Feng Shui woodlands were grouped into four types according to species composition: 1) Woodlands dominated by *Cinnamomum camphora*, in which large specimens of *Cinnamomum camphora* and *Bischofia javanica* which were frequently planted by the village ancestors. 2) Woodlands dominated by *Ficus microcarpa*, where dominated by large banyans *Ficus microcarpa*, longan *Euphoria longan* and *Antidesma bunius*. They are also traditionally planted woodlands. 3) Woodlands dominated by late succession species, in which dominated by some species, such as *Endospermum*, *Eleocarpus sylvestris*, *Persea breviflora* and *Sarcosperma laurinum*, which existed when the village was founded. 4) Woodlands dominated by early succession species, in which there is a large proportion of commonly occurring species such as *Aporusa*, *Sterculia*, *Aquilaria*, *Schefflera* and *Persea thunbergii*, which usually exist in the early stages of succession.

A floristic checklist of selected Feng Shui woodlands throughout the Territory was completed by Chu (1998). There were total 567 vascular plant species belonging to 140 families identified in 112 woodlands with a detail survey of 19 of them. Of those 567 species, 69 species were classified as important species. Eighteen taxa (17 species and 1 variety) were found to be new to Hong Kong and six of which are still only known from Feng Shui woodlands. Some species which were new to Hong Kong are *Popowia pisocarpa* (Bl.) Endl., *Mapania silhetensis* H. Uittien and *Castanopsis fordii* Hance. The three most species-rich families recorded are Leguminosae, Euphorbiaceae and Rubiaceae, with 37, 35 and 33 species respectively. There were also some species found to be apparently typical of Feng Shui trees, such as *Adenanthera pavonina* var. *microsperma*, *Bridelia insulana* and *Casearia villilimba* which are not found in other vegetation types.

2.2.4 Functions of Feng Shui Woodlands

Feng Shui woodlands serve the villages with many functions. In view of Feng Shui principles, the strip of woodland at the foot of hill slope protects the villages by slowing down the flow of strong *yang* forces coming down the slopes (Hase *et al.*, 1992; Webb, 1996).

In the case of Lam Tsuen Valley (Webb, 1996), there is a gap in the line of hills, through which the indigenous villagers believe that powerful negative forces "*Sha*" can flow and bring bad fortune to the villages. Therefore, the woodland behind the village can, firstly, protect the village from this bad influence by shielding any negative "Sha" force flowing through the gap or blocking the view of the gap; secondly, reinforce the "mountain star" of the village in the direction in which there is a lack of high ground behind the village; thirdly, protect the village from the adverse effects of typhoons which blow through this gap.

Similarly, extensive views of the sea are thought to be undesirable in coastal area. Thus, the villages sited their Feng Shui woodlands to block the views of sea in order to screening any negative Feng Shui forces (Webb, 1996). From this viewpoint, it can explain why some villages do not possess any Feng Shui woodlands. Since if the village is sited in a "good position", it can "borrow" or share the Feng Shui woodlands of another village(s) in order to protect that village from bad "Sha" negative force (Webb, 1996).

Apart from Feng Shui function, Feng Shui woodlands also serve other functions. Five major functions of the woodlands were concluded by Webb (1996) after interviewing indigenous villagers. They are: 1) fire woods; 2) medicines; 3) fruits; 4) timber and bamboo; and 5) shelter from typhoons and protection from landslides and flooding (Webb, 1996). These benefits brought by Feng Shui woodlands can be divided into two types. Firstly, the villagers derive benefits from the woodlands through planting and harvesting trees of special values, such as of economic value or traditional medicinal value, in the woodlands. For examples, *Aquilaria sinensis* were planted and used to make incense sticks, *Bambusa* spp. (Bamboo) were planted for structural purpose. Other edible fruits such as Litchi and Longan were also planted for economic purpose (Thrower, 1975). Besides, there is evidence that villagers cut the trees inside the woodlands as a source of fuel wood in the period of Japanese occupation (Webb, 1996).

The second type of benefits is mainly derived from the physical or physiochemical characteristics of the woodlands. The woodlands keep the village warm in the winter by blocking cold northern wind while create a lot of shades and keep it cool in the summer (Hammond, 1992). In addition, the trees inside help keep local air quality fresh and stabilize the slopes behind the villages to prevent landslides, which create a healthy and safe environment for the villagers.

With respect to these practical benefits as well as the Feng Shui functions stated above, they could be regarded as a kind of “sacred” woodlands to the villages (Webb, 1996).

2.2.5 Threats to Feng Shui Woodlands

Since Feng Shui woodlands are located behind the villages which are mainly concentrated in the New Territories, especially in the northeast part, and many of them are not all represented in neither country parks nor special areas (Chu & Xing, 1997; Chu, 1998), they are undoubtedly facing a great pressure from various kinds of development and construction activities such as village expansion or village development as well as the general development pressure on the lowland in Hong Kong (Chu & Xing, 1997).

The greatest threat identified by Webb (1996) is from building a three-storied house there (The New Territorial Small House Policy (1972)) because the only available land is in, or at the edge of the Feng Shui woodlands. Other threats related to building and development activities are constructing buildings and roads; building an open storage area for construction materials, containers and vehicle dumps; developing borrow area, golf course and so on. Such kinds of infrastructure can only be built often at the expense of the Feng Shui woodlands. Apart from construction and development activities, fire damage and rubbish dumping also pose threats to Feng Shui woodlands. The effect of these threats exerted on Feng Shui woodlands would be great if the size of the woodland is small (Webb, 1996).

2.3 Summary

To conclude, remotely sensed technique, usually incorporated with GIS, has been widely applied in landscape analysis in the past decades. Calculating landscape metrics to characterize the landscape of interest to infer ecological processes and study human activity impact is also prevalent. However, some points should be noticed in measuring the landscape pattern, firstly, the scale, including spatial extent and resolution, especially for those studies involved comparison with other spatial data of different scale; and secondly, the redundancy of various landscape metrics.

Feng Shui woodlands in Hong Kong are definitely important in their ecological, cultural and historical values. Despite the importance, they are under threat imposed by village development. Using remotely sensed approach, integrated with GIS, to study the landscape ecology of Feng Shui woodlands and their surroundings would be advantageous in giving us a more comprehensive and holistic view of landuse pattern in Feng Shui woodlands' neighbourhoods.

Chapter 3 Methodology

3.1 Introduction

As pointed out in the last chapter, there was much effort put on studying the species composition of Feng Shui woodlands (Thrower, 1975; Webb, 1996; Chu & Xing, 1997; Chu, 1998), which indicated the ecological importance of Feng Shui woodlands. Webb (1996) also studied the social and cultural interaction between woodlands and the villagers living around. However, none are known about the landuse pattern around Feng Shui woodlands, which may affect the "health" of the woodlands. Investigating landscape ecology of Feng Shui woodlands enables us to look into the landuse composition and interaction between the woodlands and the surroundings, which fills in the knowledge gap of the surrounding landuse impact imposing on Feng Shui woodlands.

Remotely sensed technique was adopted to identify Feng Shui woodlands by Webb (1996) and Chu (1998). They examined aerial photographs taken from 1986-1990 (Webb, 1996) and at 1994 (Chu, 1998) to determine and identify the number and location of Feng Shui woodlands adjacent to villages in Hong Kong, and then compared with the 1945 air photos to indicate the change (Webb, 1996; Chu, 1998). Air photograph is useful in revealing the fundamental plan of the phenomena of the earth's surface (Troll, 1971) and in portraying the ecosystem composing the landscape as well as its boundary, especially in vegetation structure (Forman & Gordon, 1986). Applying remote sensing technique in landscape analysis is not uncommon. It provides a holistic view of the focal patch and its neighbourhood. Interpretation of the interaction between the focal patch and its neighbourhood can be made.

This chapter begins with a brief description of the study site and then is followed by describing the four main stages of the study which are carried out to investigate landuse interaction between Feng Shui woodland and its surroundings in the Northeast part of New Territories. These four stages are 1) identification of Feng Shui woodlands by using satellite imagery; 2) data extraction; 3) construction of GIS database; and 4) analysis of landscape ecology of Feng Shui woodlands in terms of landscape metrics and landuse composition.

3.2 Study Site Description

The population of Hong Kong is expected to increase up to 8.3 million in 2011 (Planning Department & Territory Development Department, 2003a) and obviously, there will be an urgent need of land in the future in order to provide many socio-economic necessities such as housings, commercial and institutional facilities. Developing the New Territories will be one of the main ways to help fulfill the land requirement. The Planning and Lands Bureau aimed at increasing the ratio of population living in the New Territories from 35% to 45% by 2011 (Housing, Planning and Lands Bureau, 1999 Press Releases). It can be seen that the New Territories is under a great development pressure and the development should be planned and assessed carefully before any actions are taken.

In addition, in the Territorial Development Strategic Review '96, the Northeast part of the New Territories is designated as a unique area which is defined as "All such areas (unique area) are distinguished by natural attributes that demand the highest levels of protection against incompatible development and management to control unacceptable levels of use." Also, provision of tourist and recreational facilities as well as conservation are two broad development principles in the development strategy of the Northeast part of the New Territories (Planning, Environment and Lands Branch, 1996).

The Northeastern part of the New Territories contains new towns such as Sheung Shui and Fanling and some suggested areas for future development such as Kwu Tung, Ping Che and Ta Kwu Ling (Planning, Environment and Lands Branch, 1996; Planning Department, 2002). According to the Planning and Development study on North East New Territories (2003), Kwu Tung North and Fanling North will be developed into new towns, planned to accommodate a population of 100,000 and 80,000 respectively. Land will also be reserved at Ping Che and Ta Kwu Ling for open storage (92 ha) and industrial use (15 ha) (Planning Department and Territory Development Department, 2003a). These areas contain many lowland rural areas, old villages, farmlands, shrublands and woodlands, some of which are ecologically and culturally important but also possess great developmental potential for urban use. Apart from the ecological aspect, there are also many sites of great historical value in the Fanling North area. For example, the walled villages such as Lo Wai, Ma Wat Wai, and Tung Kwok Wai as well as the ancestral halls in the Lung Yeuk Tau Cultural Heritage Trail are culturally and traditionally important. These heritage resources have integral value by providing a means of interpreting social, cultural and economic changes and human understanding in the past (Planning Department & Environment Resources Management, 2000) and will be integrated into the future new town planning so as to attract local residents and tourists to visit and to achieve sustainable development (Planning Department & Environment Resources Management, 2000; Planning and Lands Bureau, 2000 Press Releases).

3.3 Identification of Feng Shui Woodlands

3.3.1 Acquisition and Pre-processing of Remote Sensing Data

An IKONOS imagery taken on the 1st November 2000 covering the Northeast part, including Sheung Shui, Fanling, Kwu Tung, Ping Che and Ta Kwu Ling, of the New Territories of Hong Kong is acquired for this study (see Figure 3.1).

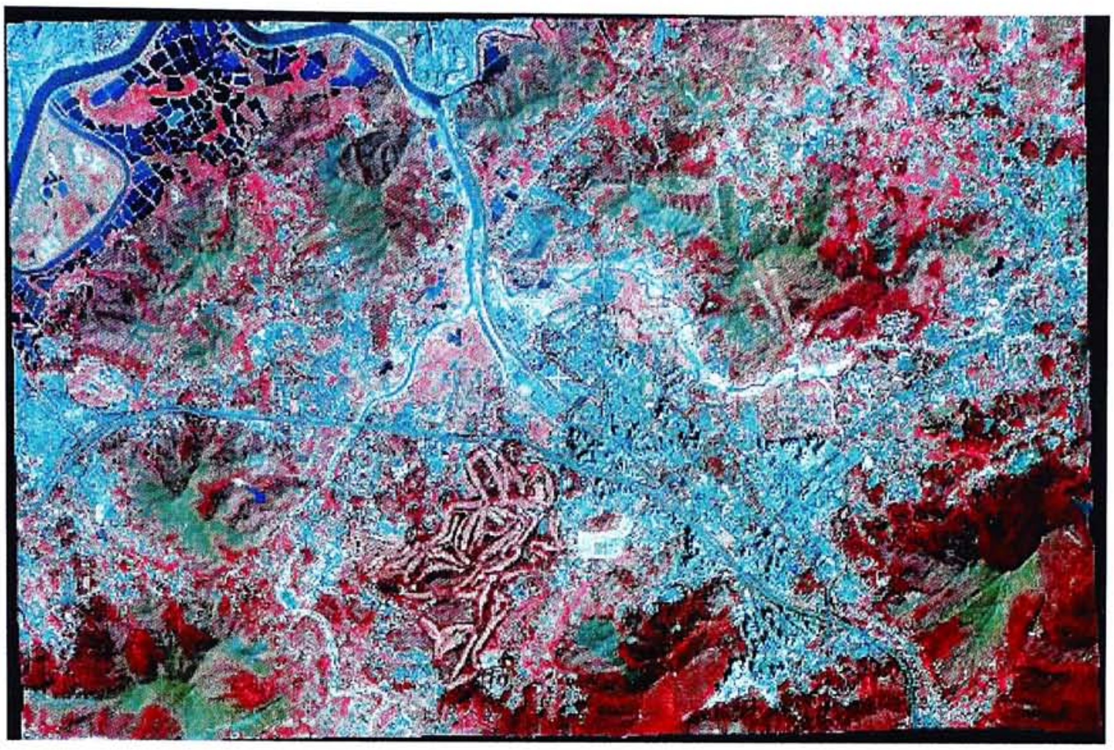


Figure 3.1 False Colour IKONOS composite (IR, R, G)

covering the NENT

This digital data possesses the highest publicly available spatial resolution, one-meter panchromatic and four-meter multispectral images (Toutin & Cheng, 2000), at the time of this study, which provides much detail of the earth's surface for researchers. By using PCI Geomatica V8.2.1 OrthoEngine® (2003), the imagery is orthorectified with reference to the 5-meter Digital Elevation Model (DEM) archived in the Department of Geography and Resource Management, CUHK. Sixteen Ground Control Points (GCPs) are collected at road junctions and river intersections from both of the imagery and the DEM, with the overall RMS error of 0.39 pixels (see Figure 3.2). The ortho-image is resampled based on the nearest resampling method.

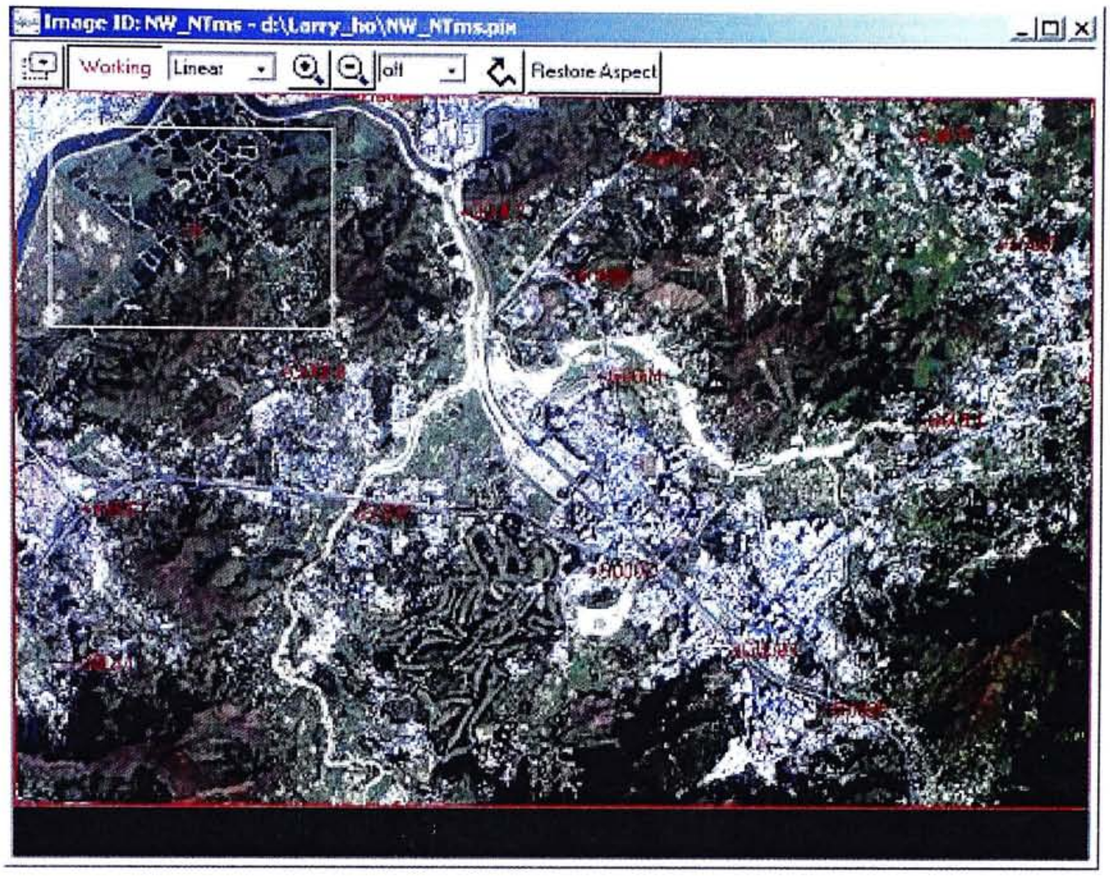


Figure 3.2 Collection of GCPs (shown by the red dots)

Radiometric correction is performed to, firstly calibrated to at-aperture in-band radiance by the equation (source: www.spaceimaging.com):

$$L_{i,j,k} = \frac{DN_{i,j,k}}{CalCoef_k} \qquad \text{eq. 3.1}$$

where *i,j,k* is IKONOS image pixel *i,j* in spectral band *k*, $L_{i,j,k}$ is the in-band radiance at the sensor aperture (mW/cm^2*sr), $CalCoef_k$ is the In-Band Radiance Calibration Coefficient (mW/cm^2*sr*DN), and $DN_{i,j,k}$ is the image product digital value (DN). The Calibration Coefficients used are listed in the following table (Table 3.1):

Table 3.1. IKONOS Radiometric Calibration Coefficients

Band	Calibration Coefficient ($mW/cm^2*sr*DN$)
Blue	633
Green	649
Red	840
Infrared	746

(source: www.spaceimaging.com)

The calibrated radiance is further converted into reflectance. Due to the similarity in spectral characteristics between the spectral bands of IKONOS and Landsat 7 ETM+ (shown in Table 3.2), the radiometric correction method of Landsat 7 ETM+ is adopted to correct the IKONOS radiance data for the effects of sun angles, solar zenith angle, earth-sun distance and mean solar exoatmospheric irradiance. The formula is given as (sources: lipwww.gsfc.nasa.gov):

$$\rho_p = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda \cdot \cos\theta_s} \qquad \text{eq. 3.2}$$

where ρ_p is the unitless planetary reflectance, L_λ is the spectral radiance at the sensor's aperture, d^2 is square of the Earth-Sun distance in astronomical units, $ESUN_\lambda$ is the Mean solar exoatmospheric irradiances, and θ_s is the Solar zenith angle in degrees.

Table 3.2 Spectral Bandwidths of IKONOS and Landsat 7 ETM+

and ESUN$_\lambda$ values adopted

Band	IKONOS (nm)	Landsat 7 ETM+ (μm)	ESUN$_\lambda$ (W/m^2*μm)
Blue/TM1	445-516	0.45-0.52	1969.00
Green/TM2	506-595	0.52-0.60	1840.00
Red/TM3	632-698	0.63-0.69	1551.00
Infrared/TM4	757-853	0.76-0.90	1044.00

(sources: www.spaceimaging.com & lipwww.gsfc.nasa.gov)

3.3.2 Identification of Feng Shui Woodlands

A supervised approach with maximum likelihood classification (MLC) is used to produce the thematic map of the study area. Apart from the four radiometrically corrected multispectral bands (Red, Green, Blue and near Infrared), textural data computed based on Grey Level Co-occurrence Matrix (GLCM) is also incorporated into classification in order to improve the classification accuracy (Franklin *et al.*, 2000; Narasimha Rao *et al.*, 2002). A list of GLCM textural data is generated by PCI Geomatica Xpace v8.2.1 (2003) based on a 3 X 3 pixel windows. Among the generated textural data, only 3 textural data, namely Homogeneity, Dissimilarity and Entropy are selected as additional input channels for classification after visual examination of the generated textural measures. The selection criterion is that the best separation of Feng Shui woodlands from other landscape elements is observed. The textural data used in this study will be discussed briefly.

Homogeneity is the same as Inverse Difference Moment, IDM, and measures image homogeneity as it assumes larger values for smaller grey tone differences in pair elements (Narasimha Rao *et al.*, 2002). Its formula is given by:

$$HOM = \sum_{i=0}^{Ng-1}\sum_{j=0}^{Ng-1} p(i,j) / \left[1 + (i-j)^2\right] \qquad \text{eq. 3.3}$$

where *Ng* is the number of grey levels and *p(i,j)* is the probability of co-occurrence of grey levels *i* and *j*. Figure 3.3 shows a graphical display of homogeneity data computed.

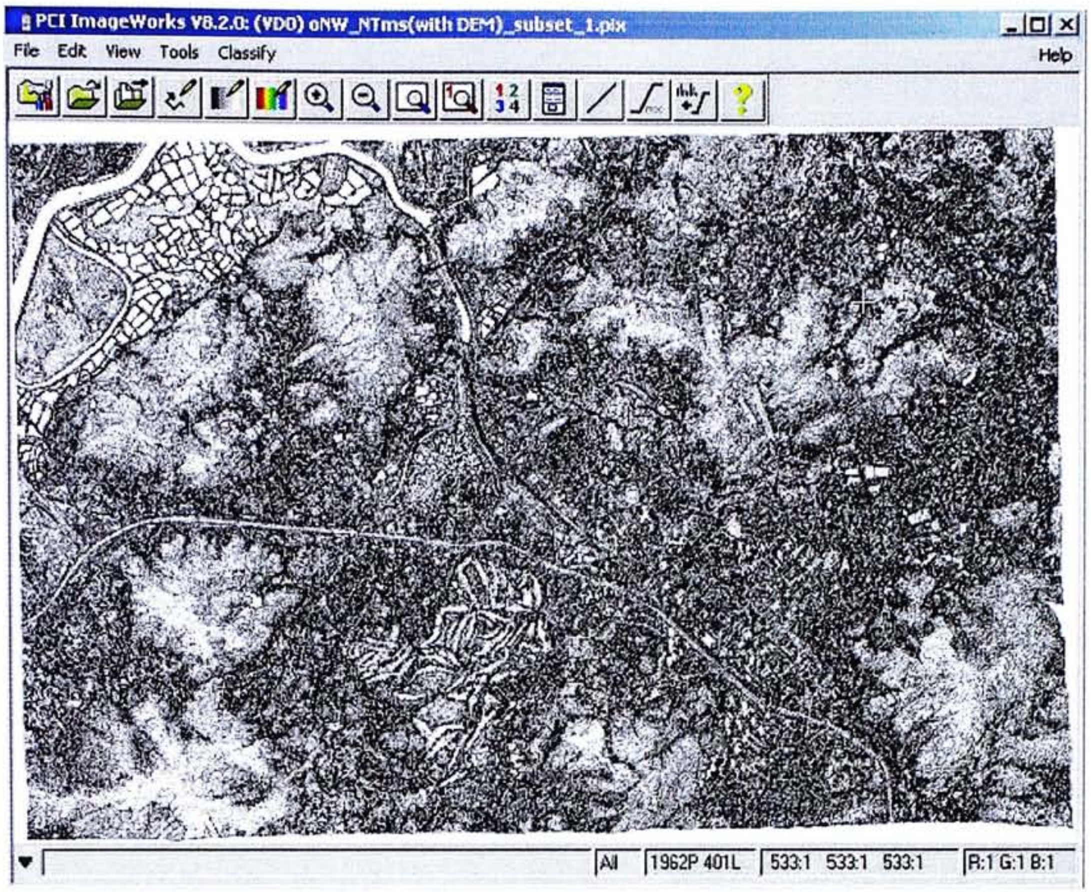


Figure 3.3 Visual display of GLCM textural data—Homogeneity

Dissimilarity measures the heterogeneity of the grey levels and its formula is give by:

$$DSM = \sum_{i=0}^{Ng-1} \sum_{j=0}^{Ng-1} Abs(i-j)p(i,j) \qquad \text{eq. 3.4}$$

Higher values of dissimilarity indicate and the local region has a high contrast or coarser textures. The data is visually shown in Figure 3.4.

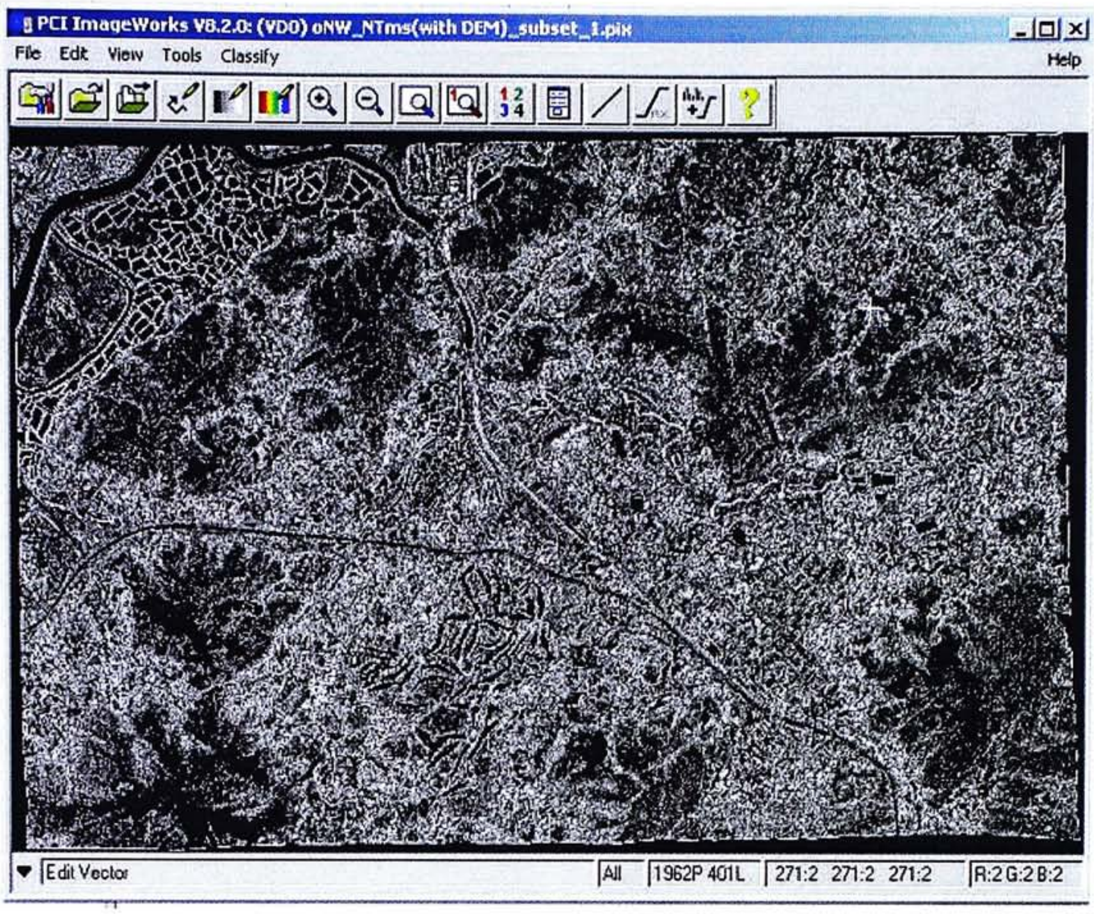


Figure 3.4 Visual display of GLCM textural data—Dissimilarity

Entropy measures the disorder of an image and its equation is given by:

$$ENT = \sum_{i=0}^{Ng-1}\sum_{j=0}^{Ng-1} p(i,j)\log(p(i,j)) \qquad \text{eq. 3.5}$$

Its value would be high when the image is not texturally uniform or the elements of GLCM have relatively equal values. It is conceptually inversely correlated with *Homogeneity* (Narasimha Rao *et al.*, 2002). Figure 3.5 shows the data computed graphically.

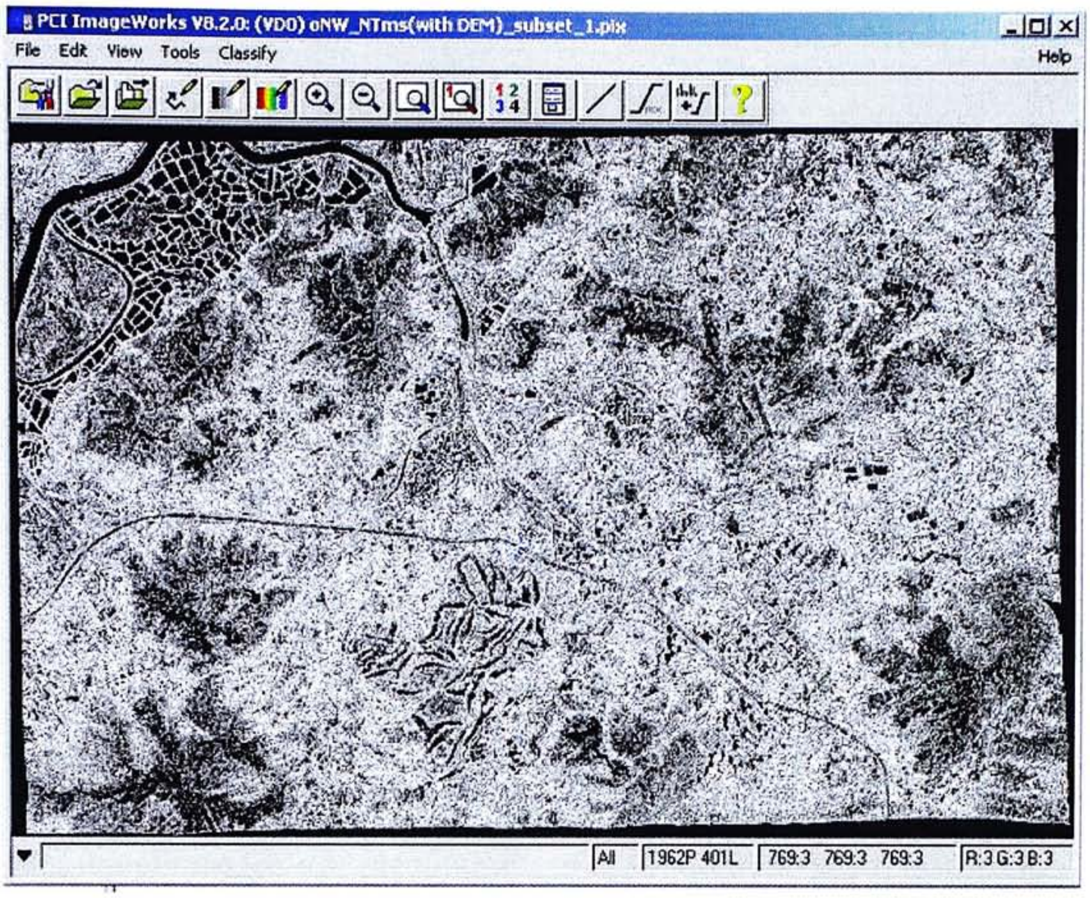


Figure 3.5 Visual display of GLCM textural data—Entropy

Since the classification results showed that Feng Shui woodlands are spectrally and texturally similar to other trees or woodlands, Feng Shui woodlands could not be separated and mapped out unless the villages' locations are known. Thus, a set of geo-referenced village polygons, provided by Lands Department, HKSAR, is used to indicate the village locations on the image in order to aid the identification of Feng Shui woodlands. Feng Shui woodland locations that are identified by Webb (1996) are also used to help identify the woodlands, with the aid of 1:20000 topographic maps and 1:7500 Outline Zoning Plan (OZP) provided by the Lands Department and Town

Planning Board respectively. With these references, woodland patches proximate to the villages as well as other patches of woodlands with similar shape and size are identified and delineated.

3.4 Extraction of Landscape Metrics and Landuse composition

3.4.1 Landscape Metrics of Feng Shui Woodlands

Patch level metrics are calculated using FRAGSTATS 3.3 (McGarigal *et. al.*, 2002) for each identified patch of woodlands. They are *Area, Perimeter, Radius of Gyration, Perimeter-to-Area Ratio, Shape, Fractal Dimensions, Related Circumscribing Circle* and *Contiguity*. They are used to investigate the physical characteristics of the identified woodland patches and will be discussed as follows.

Area of each patch is expressed in hectare and is fundamental to landscape ecology study. This information is the basis for many other metrics such as Perimeter-to-Area ratio and Fractal Dimension. In addition, according to the Species-Area relationship (MacArthur & Wilson, 1963), there is a linear relationship between the logarithm functions of number of species and size of an isolated patch. For instance, habitat destruction may induce loss of number of species diversity (Ney-Nifle & Mangel, 2000).

Perimeter includes any internal holes in a patch and is measured in meter. It, as the Area does, forms the basis for many other metrics, especially those related to shape complexity. Specifically, it also reflects the amount of edges. The intensity and distribution of edges constitute a major aspect in landscape pattern (McGarigal *et. al.*, 2002).

Radius of Gyration measures the mean distance (m) between each cell in the patch and the patch centroid. Its equation is given as:

$$GYRATE = \sum_{r=1}^{z} \frac{h_{ijr}}{z} \qquad \text{eq. 3.6}$$

where h_{ijr} is the distance between cell *ijr* and the centroid of the patch *ij*, based on cell center-to-cell center distance; *z* is the number of cells in patch *ij*. It is used to measure the patch extent and is affected by both patch size and patch compaction. It can also be considered as a measure of the average distance an organism can move within a patch before encountering the patch boundary from a random starting point. (McGarigal *et. al.*, 2002).

For the rest of landscape metrics, they mainly contribute to knowledge of the shape complexity of woodland patches, which can indicate the degree of disturbance suffered by the woodlands since human create simple shape (O'Neill *et al.*, 1997). *Perimeter-to-Area* ratio, P/A ratio, is a simple measure of shape complexity of a patch. However, it varies with the patch size since it is not standardized with a simple Euclidean Shape (McGarigal *et. al.*, 2002). The *Shape* Index corrected for this size-dependent problem by adjusting for a square, or almost a square and is the simplest means to measure the shape complexity. Its equation is given as

$$SHAPE = \frac{P_{ij}}{\min P_{ij}} \qquad \text{eq. 3.7}$$

where P_{ij} is the perimeter of the patch *ij* and min P_{ij} is the minimum perimeter of the patch *ij*, which is adjusted to a square or almost a square (McGarigal *et. al.*, 2002). Another metric, *Related Circumscribing Circle*, estimates the patch shape against the smallest circumscribing circle which is calculated by the diameter measured as the maximum distance between periphery cells based on outer edge-to-outer edge distance. It provides a measure of overall patch elongation. Its equation is given as,

$$CIRCLE = 1 - \left(\frac{A_{ij}}{A_{ij}^{s}}\right) \qquad \text{eq. 3.8}$$

where A_{ij} is the area of the patch *ij* and A_{ij}^{s} is the area of the smallest circumscribing circle (McGarigal *et. al.*, 2002).

Fractal Dimension is commonly used to measure the shape complexity since, as the *Shape* index, it is also corrected for the size-dependent problem. The *Fractal Dimension* used here is adjusted to correct for the raster bias for the perimeter and its equation is given as

$$FD = \frac{2\ln(0.25P_{ij})}{\ln A_{ij}} \qquad \text{eq. 3.9}$$

where A_{ij} is the area of the patch *ij* (McGarigal *et. al.*, 2002). It is also shown to be correlated with the degree of human manipulation of the landscape (O'Neill, 1988).

Contiguity index assesses the spatial connectedness, or contiguity, of cells within a grid-cell patch to provide an index of patch boundary configuration and thus patch shape (LaGro, 1991). Its equation is given as:

$$CONTIG = \frac{\left(\frac{\sum_{r=1}^{z} C_{ijr}}{A_{ij}}\right) - 1}{v - 1} \qquad \text{eq. 3.10}$$

where C_{ijr} is the contiguity value for pixel r in patch ij; and v is the sum of the values in a 3-by-3 cell template (McGarigal *et. al.*, 2002).

3.4.2 Estimation of Landuse Composition in Feng Shui Woodlands' Neighbourhood

Firstly, the thematic map generated by classification is further grouped into five landuse categories. They are 1) Built-up area (including Road, non-village type Building, open storage area and other concrete artifacts); 2) Vegetation (including farmland, grassland, and other non-Feng Shui woodlands); 3) Village; 4) Water body (including River, Pond); and 5) Feng Shui woodlands. With the aid of ArcView® 3.2, the landscape composition of each patch of woodlands is estimated by calculating area of each kind of landuses within 500 meters, at a 50-meter interval, from the outer boundary of each cardinal patch of the identified woodlands and expressed as percentage of landuse. This measurement allowed us to observe the change of the landuse composition surrounding each identified woodland patch across 500 meters.

These landuses may have various impacts on Feng Shui woodlands. For instance, large proportion of built-up area in Feng Shui woodlands' surrounding indicates high intensity of development pressure, construction impacts and trespassing effects on Feng Shui woodlands while vegetation covers near Feng Shui woodlands is supposed to buffer these adverse effects or relieve the pressure posed by built-up area.

More specifically, four of five landuse compositions calculated within 100 meters, 300 meters and 500 meters of each Feng Shui woodland patches, namely, Built-up area, Vegetation, Village and Feng Shui woodlands, are undergone factor analysis for further analysis. The reason of why not using percentage of water body as one of the inputs in factor analysis and correlation analysis is that the estimated percentage of water body is relatively small, ranging from 0% to 6.6%, as compared with another four types.

3.5 Construction of a Geographical Information System (GIS) Database

A GIS database is constructed to store the extracted Feng Shui woodland patches, as well as the calculated landscape metrics, the estimated landscape compositions, the factor scores extracted by factor analysis and the cluster ID generated in clustering analysis. GIS facilitates integrating the data of numerous and complex forms as well as storing, retrieving and analyzing these data. Various layers such as village polygon, Feng Shui woodland polygons and the thematic map generated are overlaid in order to display the spatial pattern of the identified Feng Shui woodlands as well as the spatial distribution of the woodlands of different characteristics such as size, shape and landuse composition.

3.6 Analysis of Landscape Ecology of Feng Shui Woodlands

Factor analysis is performed to reduce the data dimensions of the landscape metrics and the estimated landuse composition by using Principal Axis Factoring (PAF) and Principal Component Analysis (PCA) respectively. The extracted factors are then rotated by varimax rotation which would maximize the variance of the squared loading across variables (Sharma, 1996, p138). Interpretation of these derived factors is based on examining the extracted communalities and structure loadings of variables. In addition, since various kinds of landuses near Feng Shui woodlands may pose various effects on Feng Shui woodlands, correlation analysis is performed to correlate the rotated factors to see whether the surrounding landuses would affect Feng Shui woodland's physical properties such as size and shape. For example, a high portion of built-up area may shape Feng Shui woodlands into small and simple woodlands.

Besides, non-hierarchical *K-means* clustering is performed to identify groups of woodland patches which are similar to each other with respect to the factors derived from the factor analysis. It is aimed at forming homogeneous groups or clusters which help interpretation and description of the physical and landuse composition characteristics of each identified woodland patch easier. Large and complex woodlands embedded in a vegetated landscape may form a group to represent a group of natural woodlands or small and simple woodlands may be observed in a highly urbanized landscape.

3.7 Summary

To summarize, Feng Shui woodlands are extracted by a supervised classification and their landscape ecology is assessed in terms of landscape metrics and their surrounding landuses. Patch level landscape metrics, such as area, perimeter and shape-related metrics, are calculated by FRAGSTATS 3.3 (McGarigal *et. al.*, 2002) for each Feng Shui woodland patch. Percentages of five types of landuses, built-up, vegetation, village, water body and Feng Shui woodlands, are also estimated as landuse composition in Feng Shui woodlands' neighbourhood. A GIS database is also constructed to store, display and help further analyze the data.

Factor analysis is performed to reduce the data dimensions of landscape metrics and landuse composition. The orthogonal factors extracted are used as inputs in correlation analysis in order to investigate any relationships exist between patch metrics factors and landuse factors. Finally, *K-means* clustering provides a classification of Feng Shui woodlands according to the patch characteristics and landuse composition.

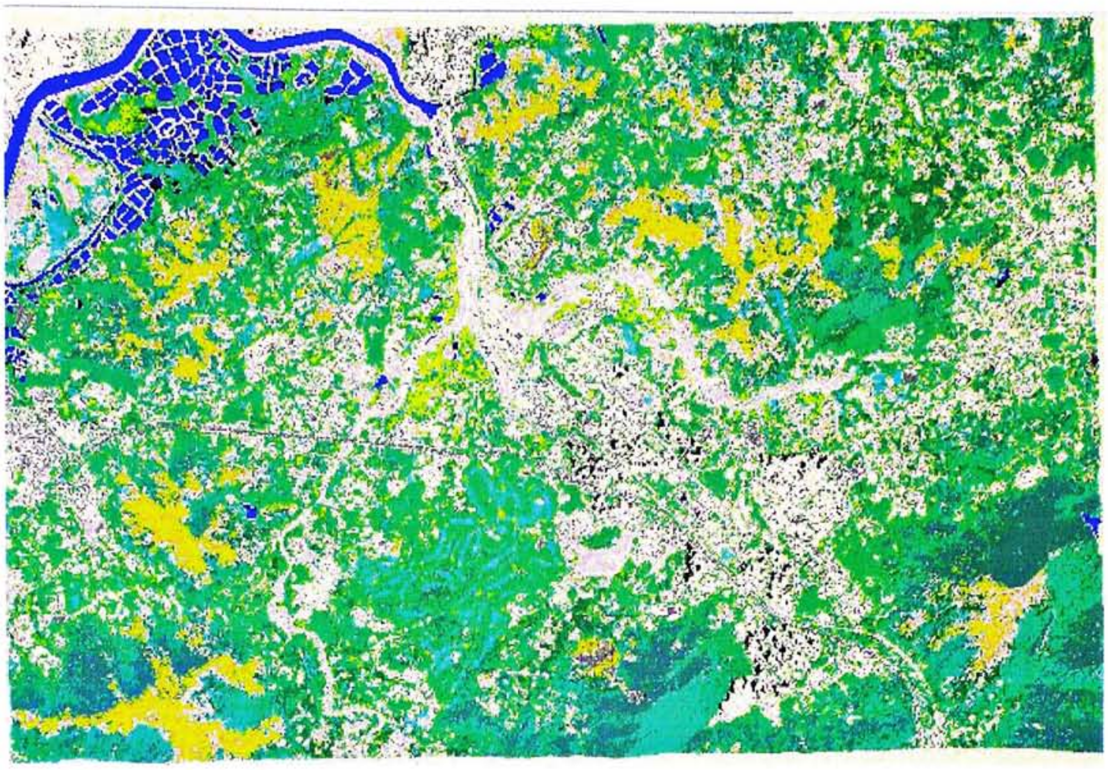
Chapter 4 Results and Discussion (I)—Physical Characteristics of Feng Shui woodlands

4.1 Introduction

The last Chapter described the methodological framework of this study. Landscape ecology of Feng Shui woodlands in the Northeast New Territories is assessed in terms of patch physical characteristics and neighbour landuse composition. Patch level landscape metrics are used to quantify the physical characteristics of each woodland patch in this study. The result is presented in this chapter.

4.2 Identification of Feng Shui Woodlands

Incorporated with GLCM textural data, woodlands are successfully extracted. As shown in the following Figure 4.1, however, Feng Shui woodlands could not be separated from other woodlands such as those formed on the slope or planted along roadside by Supervised Maximum Likelihood Classifier alone.



Legend:

Land cover	Colour
Feng Shui woodlands	
Grass	
Fields	
River and Ponds	
Buildings	
Roads	
Golf-Court	
Woodlands on illuminated slope	
Woodlands on shade slope	
Construction site	
Buildings' shade	
Bare soil	

Figure 4.1 Land cover map produced by Supervised MLC

Post-classification editing is performed in order to extract the Feng Shui woodlands by means of incorporating the Village G1000 polygons, road vectors and Feng Shui woodland locations identified by Webb (1996), which involves manually editing the boundaries of woodland patches. As listed in Table 4.1, there are 36 Feng Shui woodlands lying behind traditional villages and 14 patches of woodlands without immediately associated villages. Grid references representing centroids of the woodlands are also generated by GIS and listed in Table 4.1 to help locate the woodlands. From Figure 4.2, it can be seen that Feng Shui woodlands are scattered throughout the study site and are concentrated in the Northeastern part of the study site, i.e. near Ping Che and Lei Uk. Among the identified woodlands, three of them, Chau Tau Tsuen, Sheung Shan Kai Wat and Wo Hop Shek, are observed to have more than one patch of woodland of comparable size behind the villages. Therefore, there are totally 53 patches of Feng Shui woodlands or possible Feng Shui woodlands extracted. These 53 woodland patches would be undergone landscape analysis.

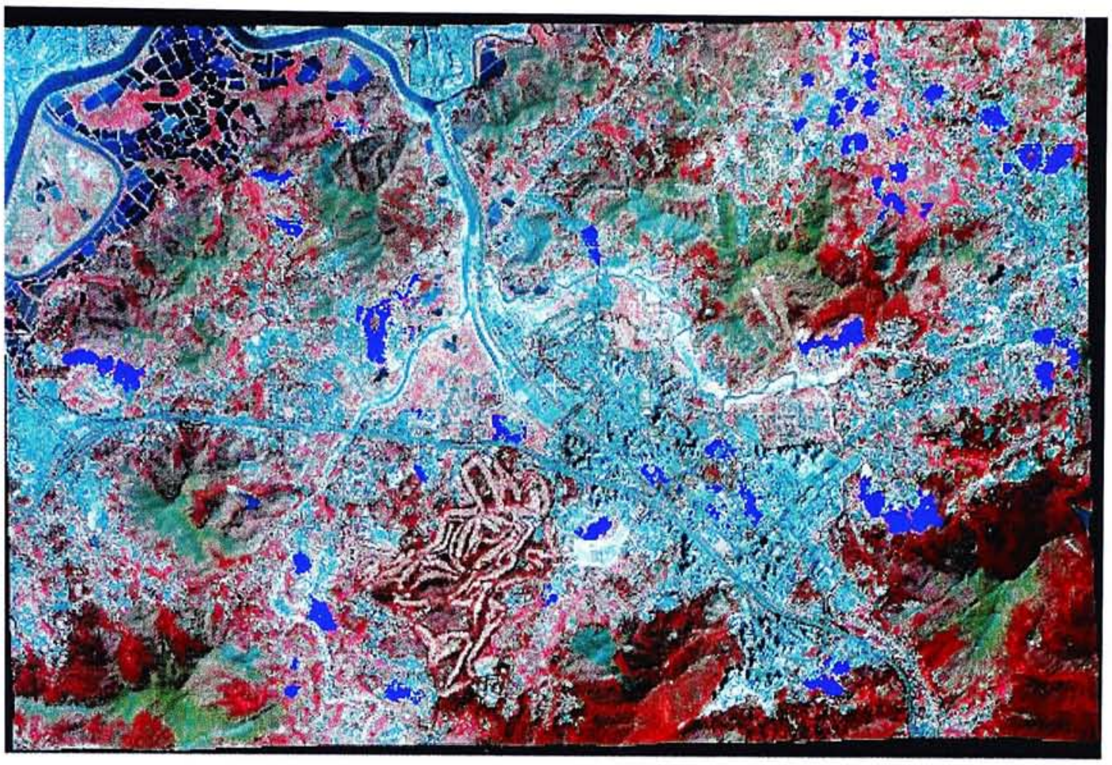


Figure 4.2 Spatial distribution of identified Feng Shui woodlands

(Feng Shui woodlands are in blue colour)

Table 4.1 Patch level metrics calculated by using FRAGSTA 3.3 (McGarigal *et. al.*, 2002)

Identified Feng Shui Woodlands	X coordinate	Y coordinate	Area (ha)	Perimeter (m)	Radius of Gyration (m)	P/A Ratio	Shape	Fractal Dimension	Circle	Contiguity
Chau Tau Tsuen	826928	840874	4.274	3456.000	87.083	808.686	4.154	1.268	0.534	0.910
Chau Tau Tsuen 2	826714	840946	1.411	1280.000	49.746	907.030	2.667	1.207	0.600	0.899
Cheung Lek	828384	838082	0.784	952.000	37.698	1214.286	2.644	1.221	0.626	0.864
Fanling Lau	832438	839776	2.328	2752.000	87.805	1182.131	4.468	1.300	0.808	0.869
Fanling Wai	832104	839694	0.611	1104.000	42.677	1806.283	3.450	1.289	0.796	0.794
Ha Shan Kai Wat	833972	842396	0.642	808.000	42.391	1259.352	2.463	1.211	0.652	0.859
HangTau	828620	838780	4.414	2472.000	88.913	559.986	2.915	1.202	0.642	0.938
HangTauTaiPo	828452	839220	1.856	1232.000	54.578	663.793	2.232	1.166	0.538	0.926
Ho Sheung Heung	829110	841284	6.960	6424.000	148.333	922.989	6.083	1.324	0.745	0.896
Hung Kiu San Tsuen	831050	842058	2.373	2584.000	88.151	1089.009	4.141	1.285	0.785	0.878
Hung Leng	835286	841786	0.123	240.000	14.271	1948.052	1.667	1.151	0.515	0.781
Kam Tsin	829504	840030	0.685	896.000	43.490	1308.411	2.667	1.226	0.747	0.850
Ko Po	835102	841270	2.739	2656.000	86.584	969.629	4.000	1.272	0.747	0.891
Lei Uk	833320	843898	0.485	1080.000	37.981	2227.723	3.857	1.319	0.761	0.750
Lin Tong Mei	829314	838090	2.158	2096.000	65.465	971.090	3.541	1.255	0.574	0.890
Ling Shan Tsuen	832126	840266	0.966	1456.000	49.744	1506.623	3.640	1.285	0.696	0.834
Liu Pok	828766	843140	0.334	704.000	29.152	2105.263	3.035	1.274	0.730	0.768

Identified Feng Shui Woodlands	X coordinate	Y coordinate	Area (ha)	Perimeter (m)	Radius of Gyration (m)	P/A Ratio	Shape	Fractal Dimension	Circle	Contiguity
Lo Wai	833790	839640	3.587	2032.000	74.602	566.459	2.674	1.188	0.374	0.937
Ma Tso Lung San Tsuen	828326	842202	1.498	2208.000	66.586	1474.359	4.452	1.313	0.764	0.836
Ma Tso Lung Shun Yee San Tsuen	828188	842636	1.850	2000.000	91.469	1081.315	3.677	1.265	0.842	0.878
Ma Wat Wai	833512	839850	3.774	3104.000	91.533	822.382	3.959	1.263	0.700	0.908
Ng Uk Tsuen	831046	839550	3.093	2672.000	81.675	863.942	3.796	1.258	0.676	0.903
Ping Che	834884	842876	2.691	2864.000	79.118	1064.209	4.313	1.289	0.624	0.882
Ping Che Kak Tin	834562	843234	2.498	2016.000	65.688	807.175	3.150	1.229	0.523	0.910
Ping Che New Village	834680	842772	0.621	544.000	30.528	876.289	1.700	1.125	0.383	0.903
Ping Kong	830692	838914	0.634	784.000	41.893	1237.374	2.450	1.206	0.731	0.862
Pun Uk Tsuen	826512	841026	3.061	2136.000	82.060	697.857	3.034	1.216	0.702	0.922
San Tong Po	835274	841058	1.147	1672.000	54.442	1457.462	3.870	1.291	0.758	0.834
Sheung Shan Kai Wat	833518	842594	0.806	808.000	50.822	1001.984	2.244	1.180	0.714	0.887
Sheung Shan Kai Wat 2	833724	842736	1.664	1640.000	55.984	985.577	3.154	1.238	0.518	0.889
Siu Hang San Tsuen	833314	841278	6.354	4480.000	160.919	705.112	4.409	1.270	0.787	0.920
So Kwun Po	831644	840050	0.890	1552.000	59.957	1744.604	4.042	1.311	0.749	0.805
Tai Po Tin	833786	843122	0.158	376.000	20.598	2373.737	2.350	1.233	0.659	0.741
Tsung Pak Long	830204	840448	1.238	1872.000	65.923	1511.628	4.179	1.305	0.707	0.828
Tsung Yuen	829348	841684	0.998	2152.000	85.309	2155.449	5.380	1.366	0.858	0.761
Tsz Tong Tsuen	833972	839726	5.480	3208.000	97.934	585.402	3.398	1.226	0.529	0.933

Identified Feng Shui Woodlands	X coordinate	Y coordinate	Area (ha)	Perimeter (m)	Radius of Gyration (m)	P/A Ratio	Shape	Fractal Dimension	Circle	Contiguity
Wo Hop Shek	833088	838196	3.038	2424.000	88.669	797.788	3.443	1.241	0.734	0.910
Wo Hop Shek 2	833240	838326	1.160	1056.000	43.795	910.345	2.444	1.192	0.540	0.899
Woods 1	835030	840932	2.728	2072.000	70.588	759.531	3.121	1.224	0.651	0.915
Woods 2	835128	842866	4.032	1904.000	86.368	472.222	2.356	1.163	0.609	0.947
Woods 3	834040	843420	1.795	976.000	52.067	543.672	1.821	1.122	0.339	0.941
Woods 4	833696	842450	2.085	2208.000	76.200	1059.094	3.781	1.270	0.714	0.882
Woods 5	833338	842978	2.358	2128.000	73.571	902.307	3.455	1.247	0.554	0.899
Woods 6	833478	843288	1.381	1584.000	48.839	1147.161	3.356	1.255	0.543	0.870
Woods 7	833306	843348	0.962	776.000	39.668	806.988	1.940	1.149	0.624	0.909
Woods 8	833222	843414	0.696	968.000	34.228	1390.805	2.881	1.241	0.521	0.844
Woods 9	833140	843220	1.386	1600.000	56.842	1154.734	3.390	1.257	0.661	0.870
Woods 10	832844	843138	0.824	680.000	39.166	825.243	1.848	1.139	0.583	0.907
Woods 11	832912	843542	0.835	776.000	37.105	929.119	2.109	1.167	0.443	0.895
Woods 12	833464	843548	1.152	1064.000	52.768	923.611	2.463	1.194	0.642	0.895
Woods 13	833334	843732	0.466	464.000	32.438	996.564	1.657	1.126	0.712	0.884
Woods 14	833456	843724	0.800	704.000	35.095	880.000	1.956	1.151	0.492	0.902
Yin Kong	829490	840564	0.150	328.000	18.915	2180.851	2.050	1.205	0.648	0.760

The rule of nomenclature of these woodlands is that firstly, village names are assigned to corresponding Feng Shui woodlands which are found to have a close relation or in close proximity with the villages. Secondly, for those Feng Shui woodlands with more than one patch of woodlands, i.e. the woodlands are fragmented or split, an extension of “2” is added after village names. For instance, Feng Shui woodlands in Chau Tau Tsuen and Wo Hop Shek are found split into two. Thirdly, for those woodlands with no observable relation with any village, which may be Feng Shui woodlands in the past, a name “Woods (number)” is given to each of those woodlands for identifying purpose.

Since in many villages, there are other small Feng Shui woodland patches or group of or individual Feng Shui trees, landscape ecology of the cardinal patch of those Feng Shui woodlands is assessed instead and represented its associated Feng Shui woodland in order not to complicate interpretation of results.

4.3 Interpretation of Landscape Metrics

Eight types of patch level metrics are calculated for each of the identified woodlands to quantify physical characteristics of the woodland patches using FRAGSTATS 3.3 (McGarigal *et. al.*, 2002) (Table 4.1). The descriptive statistics, minimum, maximum and mean values as well as standard deviation, are shown in Table 4.2.

Table 4.2 Descriptive Statistics of calculated patch level landscape metrics

	Area (ha)	Perimeter (m)	Radius of Gyration (m)	P/A ratio	Shape	Fractal dimension	Circle	Contiguity
Maximum	6.960	6424.000	160.919	2373.737	6.083	1.366	0.858	0.947
Minimum	0.123	240.000	14.271	472.222	1.657	1.122	0.339	0.741
Mean	1.906	1736.302	62.216	1134.768	3.168	1.233	0.643	0.873
S.D.	1.557	1121.542	28.766	473.405	0.973	0.058	0.120	0.052

Area is expressed in hectare and represents how large a woodland patch is, which is very important for a woodland patch since it may indicate the number of species contained in the patch. Area metrics can also be useful to identify the largest patches in a landscape, which usually represent potentially ecologically significant core areas (Leitão & Ahern, 2002). Size of identified woodlands varies from 0.12 hectares to nearly 7 hectares. The largest woodland patch identified is that lying behind Ho Sheung Heung

(6.96 hectares) while the smallest one is that behind Hung Leng (0.12 hectares). More than half of the identified Feng Shui woodlands are quite small. From Figure 4.3, 62% of identified woodland patches are less than 2 hectares. 14 patches (26%) are of medium size, between 2 to 4 hectares and only 6 patches are over 4 hectares. Average patch size is 1.9 hectares which is close to that measured by Webb (1996), 2.08 hectares.

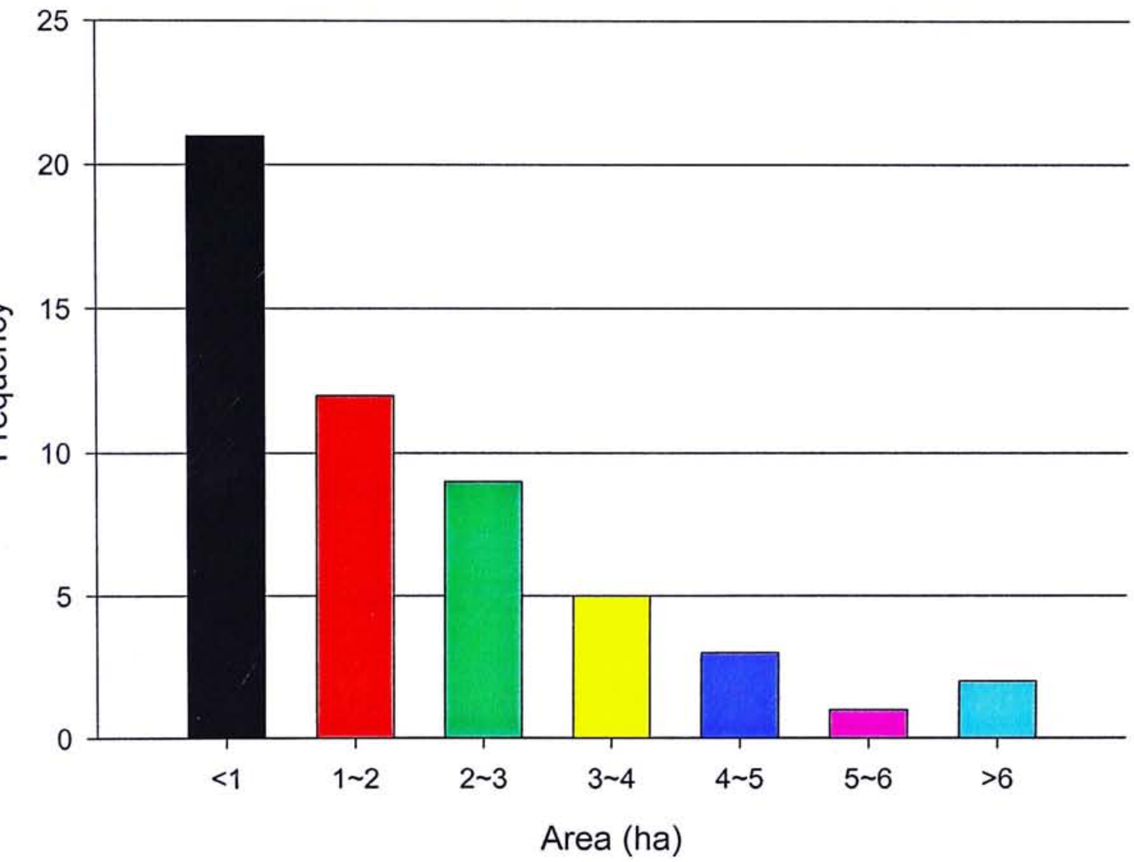


Figure 4.3 Frequency Distribution of Landscape Metrics—Area

Such a small average woodland size means that the woodlands may contain not too much species and the species inside patches and the patches themselves would be easily affected by human activities, fire damage and rubbish dumping. The characteristics of high species diversity and ecological importance reported by previous studies (Thrower, 1975; Webb, 1996; Chu, 1998) suggest that Feng Shui woodlands may be an exceptional case which small woodland area does not amount to low species diversity and richness. This can be attributable to preservation of woodlands by villagers and frequently growing trees in woodlands.

Distribution of size of identified woodlands, shown in Figure 4.3, is very similar to that of the woodlands identified by Webb throughout the territory. In Webb's study, 53% (versus 62% in this study) were found less than 2 hectares and 84% (versus 88% in this study) were found less than 4 hectares.

Each woodland size is compared with that in Webb's study (1996), if available, and listed in Table 4.3. A2000 is referred as area of woodlands estimated in this study while A1990 is referred as area of woodlands estimated in Webb's study (1996). It is found that only So Kwun Po and Tsung

Yuen are shown to be matched with Webb's study. The differences are 12% and 0.2% respectively. For other patches, some are different from Webb's measurement by even more than 10 times in the case of Liu Pok (12 times) and Tsz Tong Tsuen (21 times). The reasons are elaborated as follows.

Table 4.3 Comparison of woodland size

between this study and Webb's study (1996)

Feng Shui woodland	Area measured in this study (A2000) (ha)	Area measured in Webb's study (1996) (A1990) (ha)	Difference* (%)
Cheung Lek	0.784	0.500	56.8
Fanling Lau	2.328	1.000	132.8
Fanling Wai	0.611	1.000	-63.6
HangTau	4.414	3.000	47.1
HangTauTaiPo	1.856	1.000	85.6
Ho Sheung Heung	6.960	4.500	54.7
Hung Leng	0.123	0.500	-305.8
Kam Tsin	0.685	1.500	-119.0
Ko Po	2.739	0.750	265.2
Lei Uk	0.485	0.250	93.9
Lin Tong Mei	2.158	3.500	-62.2
Liu Pok	0.334	4.500	-1245.7
Ma Tso Lung San Tsuen	1.498	2.000	-33.5
Ma Wat Wai	3.774	3.000	25.8
Ng Uk Tsuen	3.093	2.000	54.6
Ping Che	2.691	2.000	34.6
Ping Kong	0.634	2.000	-215.7
Sheung Shan Kai Wat	0.806	2.500	-210.0
Siu Hang San Tsuen	6.354	1.000	535.4
So Kwun Po	0.890	1.000	-12.4
Tai Po Tin	0.158	0.250	-57.8
Tsung Pak Long	1.238	2.500	-101.9
Tsung Yuen	0.998	1.000	-0.2
Tsz Tong Tsuen	5.480	0.250	2092.0
Wo Hop Shek	3.038	1.750	73.6
Yin Kong	0.150	0.500	-69.9

* Difference (%) is calculated as $\frac{(A2000 - A1990)}{A2000 or A1990^{**}}$

** Whichever is smaller

Because planting trees in Feng Shui woodlands is impossible to increase woodland size too much, positive differences, i.e. A2000 is larger than A1990, can be either attributable to possible underestimation of woodland size in previous study, or to integration into other woodlands around. For the former cause, it is more applicable to those relatively "isolated" woodlands, i.e. not surrounded by other woodlands, such as the case in Ho Sheung Heung. It may indicate the difficulty and inaccuracy of using aerial photograph in estimating size of landuse patch since manual estimation would be involved whose accuracy would highly depend on the size of the grid used. For the latter one, such as the Feng Shui woodland in Siu Hang San Tsuen, it might be integrated with the woodland on the slope behind the village to form a much larger woodland.

Nearly half (12 out of 25) of the compared woodlands showed negative difference, i.e. A2000 is smaller than A1990. Provided that some woodlands are very close to roads or open storage area, they are susceptible to the impact of human activities and development such as road expansion. On the other hand, at the same time, they are protected by villagers due to Feng Shui reasons. Thus, anthropogenic activity may be able to account for the slight decrease in size of Feng Shui woodlands, such as the case in So Kwun Po. For the greater changed woodlands, the possible cause is that since in this study, woodland area (A2000) is measured for the cardinal patch while in Webb's study, area (A1990) was measured for entire woodland, the difference thus is especially large for those small woodlands such as the woodlands in Hung Leng and Liu Pok.

In Kam Tsin, after overlaying a digital road layer on the image, it is found that there is a road transverse across the woodlands whose canopies seem to fuse together when only superficial observation is made. With the assistance of a 1:20000 topographic map, it is verified that the village is bounded by the road and its Feng Shui woodland should lie within the village boundary. This suggests that the decrease in size may be due to the possible overestimation of the woodland size caused by direct interpretation from aerial photograph, or the recent development causing fragmentation in this woodland.

In Sheung Shan Kai Wat, the difference is not so much (-210%) after size of woodland of Sheung Shan Kai Wat 2 has been taken into account. A total woodland area of 2.47 hectares in Sheung Shan Kai Wat means that there is virtually no difference in woodland size between 1990 and 2000.

Perimeter is another important patch metrics which indicates amount of edges of a patch. The measured perimeter also includes internal holes. From Figure 4.4, most of the measured patch perimeter (48 out of 53) is less than 3000 meters and only five woodland patches possess perimeter greater than 3000 meters, which are also large woodland patches (>3.77 hectares). Ho Sheung Heung Feng Shui woodland is found to have the largest perimeter (6424 meters) while Hung Leng is found to have the smallest perimeter (240 meters). Perimeter can give a limited insight into shape or edge intensity of studied woodland patch.

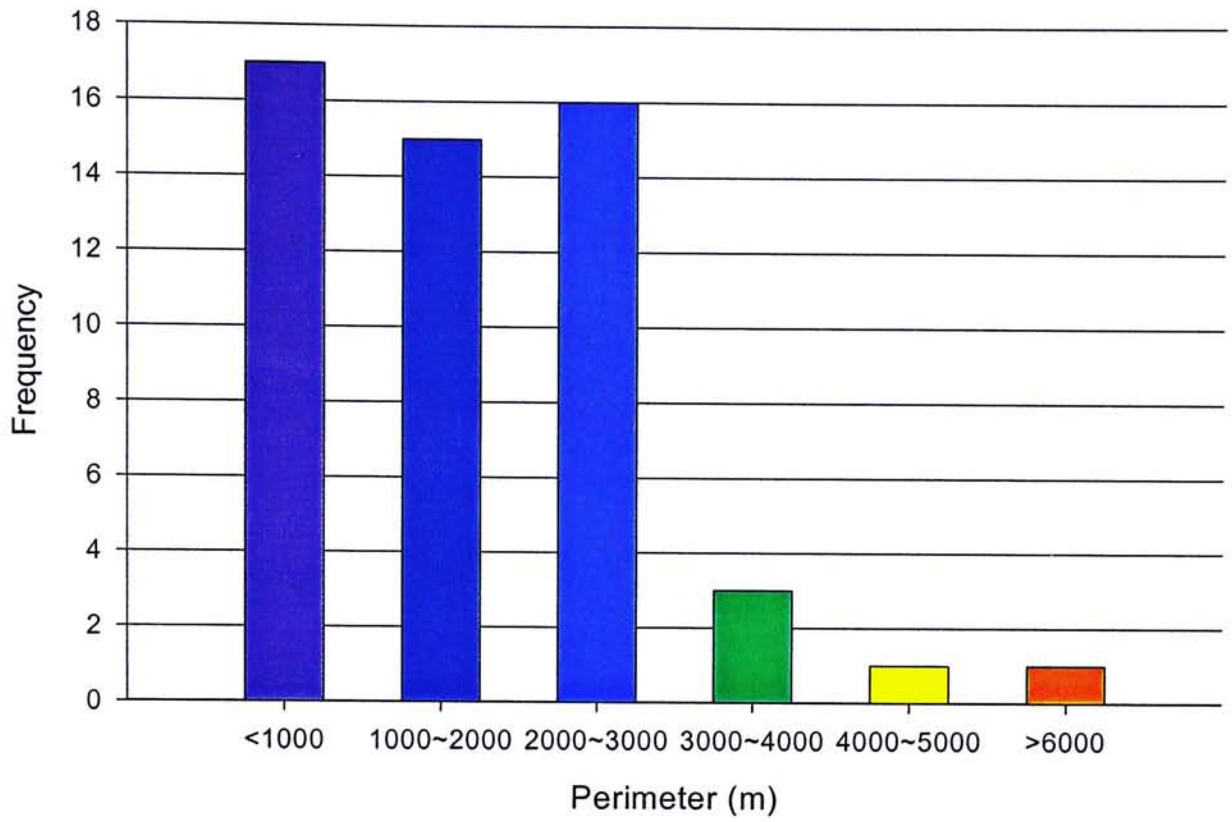


Figure 4.4 Frequency Distribution of Landscape Metrics—Perimeter

Radius of Gyration measures compactness of woodland patch, which may indicate average mammal movement within the patch. From Figure 4.5, the value of radius of gyration varies from 14.3 meters (Hung Leng) to 160.9 meters (Siu Hang San Tsuen) and it shows nearly a normal distribution with a peak at 40 to 60 meters. It can somehow compare degree of elongation among patches when their sizes are nearly the same. For instance, radii of gyration of Feng Shui woodlands in Ma Wat Wai and Ma Tso Lung San Tsuen are both 91.5 meters (correct to 2 d.p.) while their size is 3.77 and 1.85 hectares respectively. It can be seen that the Feng Shui woodland behind Ma

Tso Lung San Tsuen is more elongated than that behind Ma Wat Wai.

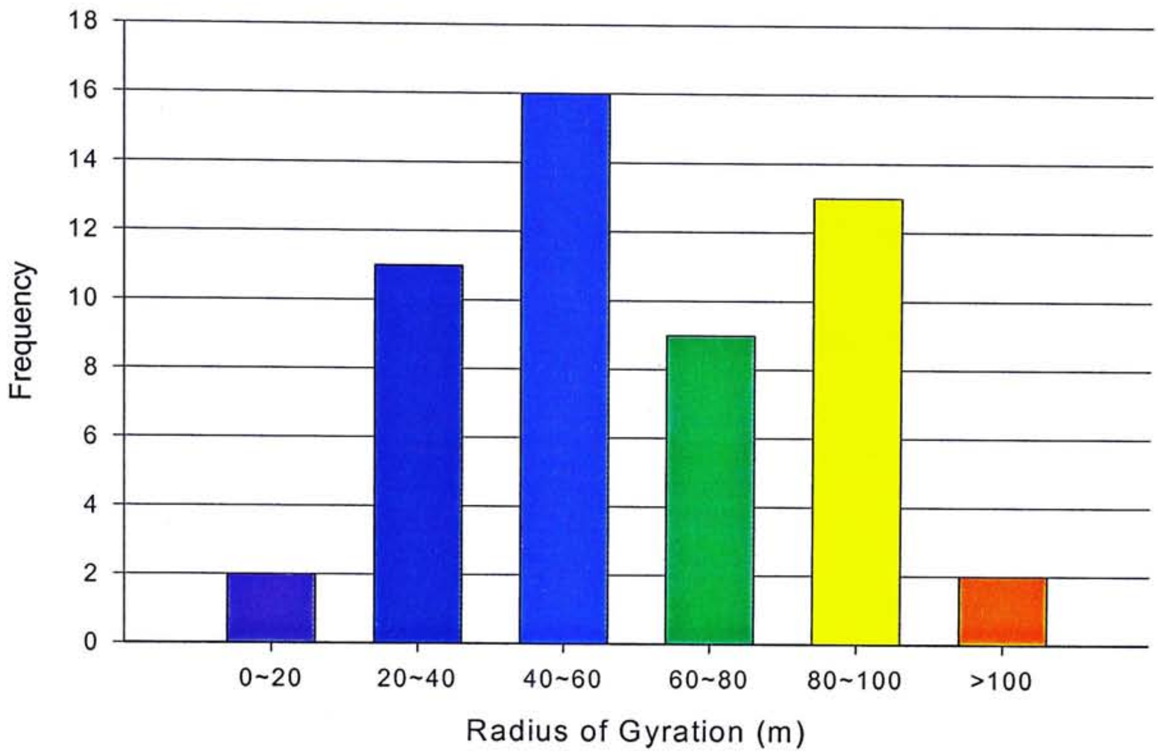


Figure 4.5 Frequency Distribution of Landscape Metrics—Radius of Gyration

Perimeter-to-area ratio, P/A ratio, represents edges suffered by the patch per unit area and is a simple measure of edge intensity or edge density, as well as shape complexity. Shown in Figure 4.6, it varies from 472.2 (Woods 2) to 2373.7 (Tai Po Tin), with nearly half falling between 800 and 1200. The results show that all woodlands possessing P/A ratio greater than 2000 are small than 1 hectare, which indicates that P/A ratio favours for smaller patches. Thus, it limits the application of this ratio.

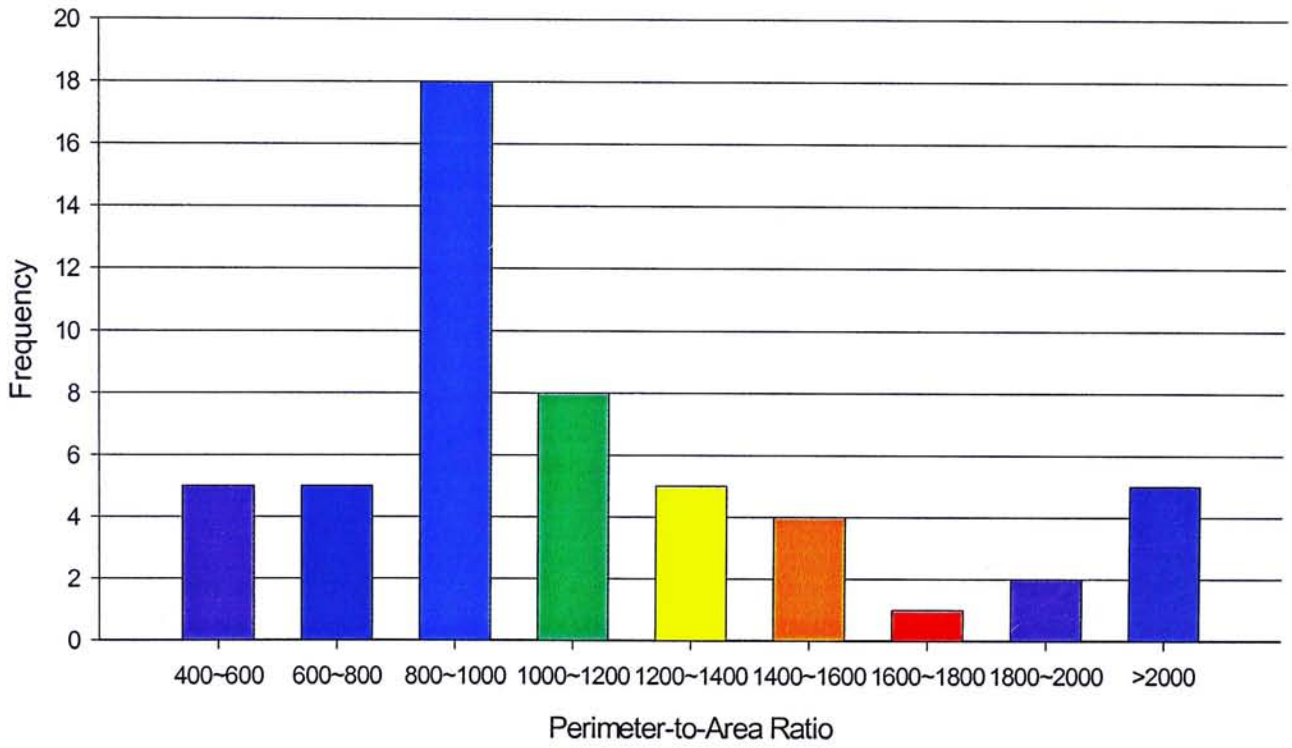


Figure 4.6 Frequency Distribution of Landscape Metrics

—Perimeter-to-area ratio

A set of metrics, Shape index, Fractal Dimension, Related

Circumscribing Circle and Contiguity index is adopted to measure shape complexity of woodland patches. Patch shape can provide insights regarding the degree of convolution of edges (Leitão & Ahern, 2002) of the patch. Boundary shape also influences interactions, such as animal movement, between the surroundings and the patch (Forman and Gordon, 1986, p175). Convoluted forms enhance these interactions with the surroundings (Forman, 1995, p124). *Shape index* corrects for the size-dependent problem of P/A ratio and measures patch shape complexity against a standard square or almost a square. From Figure 4.7, its value ranges from the simplest patch (Woods 13), 1.66, to the most complex patch (Ho Sheung Heung), 6.08.

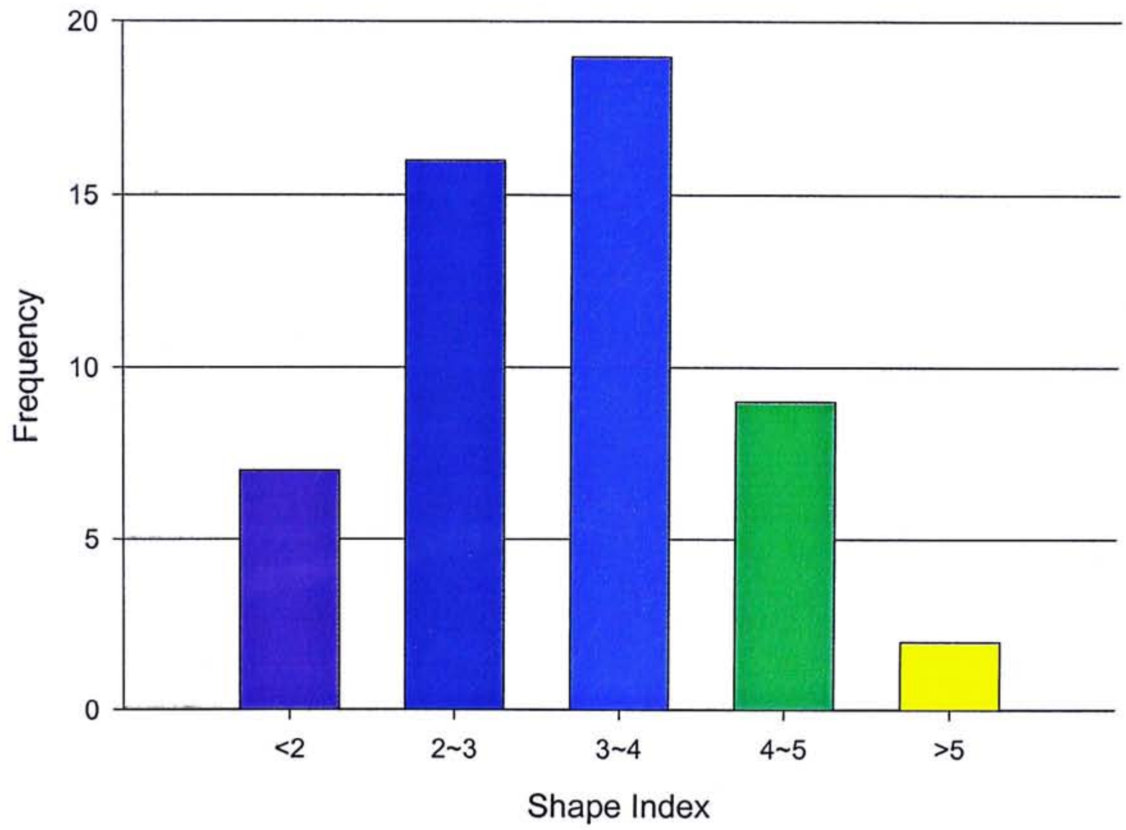


Figure 4.7 Frequency Distribution of Landscape Metrics—Shape Index

Fractal Dimension also overcomes the size-dependent problem and measures patch shape complexity as a departure from Euclidean geometry. Its value ranges from 1.12 (Woods 3) to 1.37 (Tsung Yuen). As shown in Figure 4.8, majority of woodlands (33 out of 53) fall within the value of 1.2 to 1.3. All woodlands are relatively smoother with a mean value of 1.23, which is close to that evaluated by Krummel *et al.* (1987), 1.20 $\pm$ 0.02, of deciduous forest of small area.

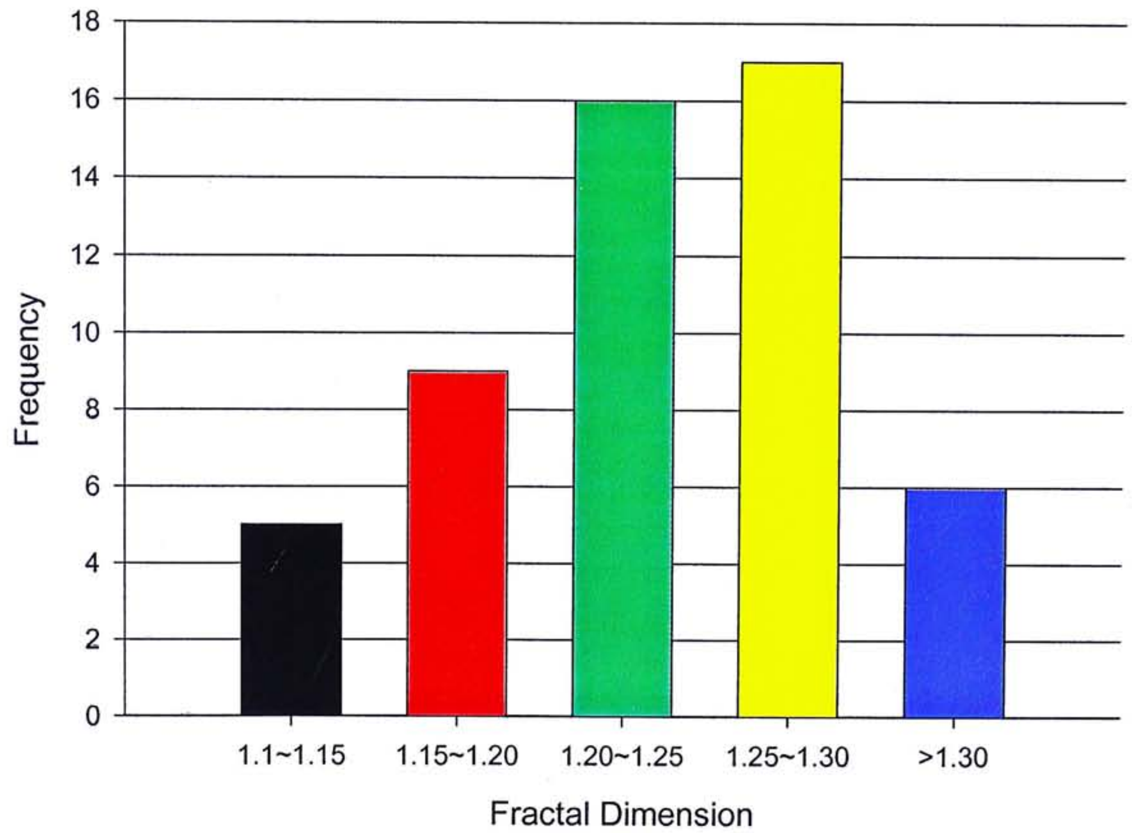


Figure 4.8 Frequency Distribution of Landscape Metrics—Fractal Dimension

Related Circumscribing Circle estimates patch shape against the smallest circumscribing circle. It can also be used to measure overall patch elongation. Observed from Figure 4.9, it exhibits a skewed distribution and most of woodlands (45 out of 53) are concentrated in the range of 0.5-0.8. Woods 3 exhibits the most circular patch (0.34) while Tsung Yuen shows the most elongated patch.

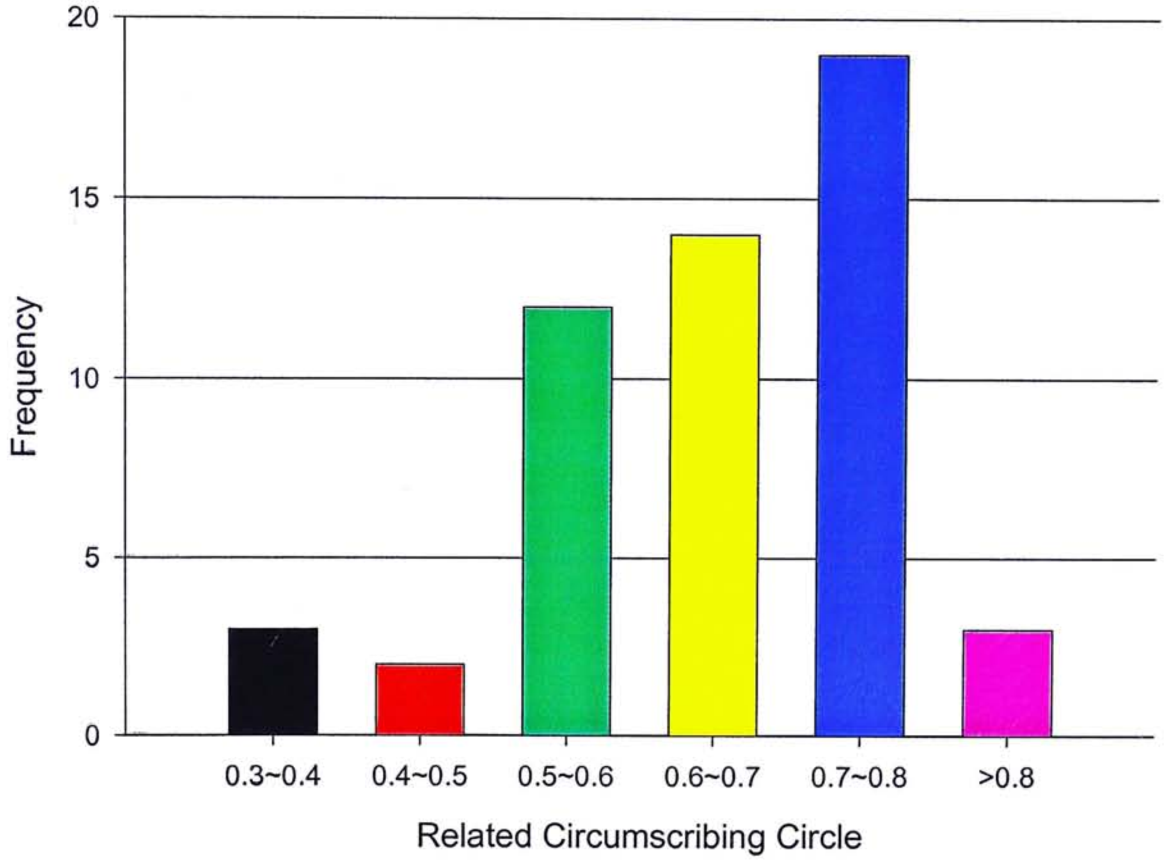


Figure 4.9 Frequency Distribution of Landscape Metrics

—Related Circumscribing Circle

Contiguity index assesses spatial connectedness of cells within a grid-cell patch to provide an index of patch boundary configuration and thus patch shape (LaGro 1991). Its distribution is shown in Figure 4.10. A large proportion of studied woodlands (40 out of 53) show a strong spatial connectedness (0.85-0.95). The lowest spatial connectedness is observed in Tai Po Tin Feng Shui woodland (0.741) while the greatest is found in Woods 2 (0.947).

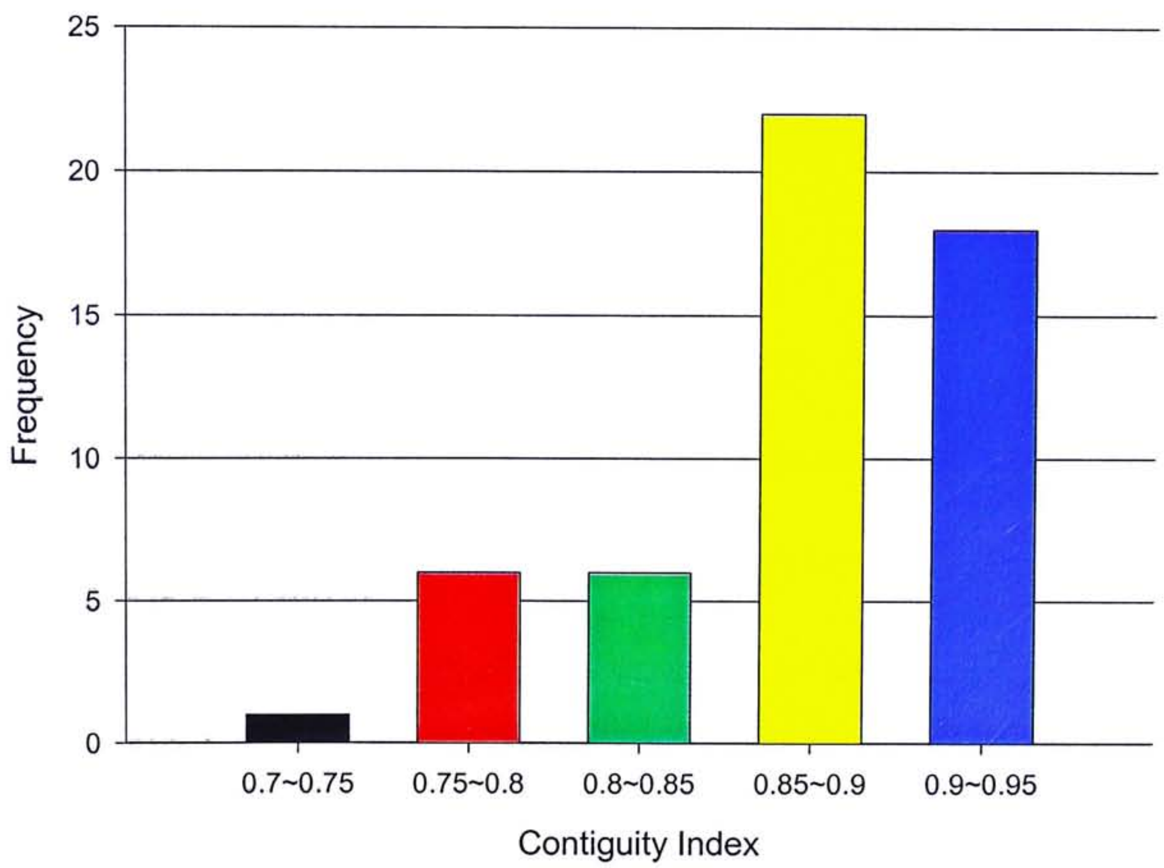


Figure 4.10 Frequency Distribution of Landscape Metrics—Contiguity Index

This set of metrics provides us an insight in shape complexity among Feng Shui woodlands. Since human activities predominate at relatively small scales and create simple shape while the natural processes predominate at larger scale and generate complex configuration (Sugihara & May, 1990; O'Neill *et al.*, 1997), small woodlands with simple shape, such as the woodlands in Hung Leng and Ping Che New Village, would indicate that the woodlands might be greatly related to or disturbed by anthropogenic activities. Small woodlands also mean less capable of containing much species and the species inside would be much vulnerable to human disturbance. Thus, small and simple woodlands, such as Feng Shui woodlands in Hung Leng and Cheung Lek, are of less ecological importance.

On the other hand, large and complex woodland patches, such as those behind Ho Sheung Heung and Siu Hang San Tsuen, would probably contain more species and the species inside would not be easily affected by human disturbance. The complex shape also means the woodlands suffer less from anthropogenic disturbance. Therefore, this kind of woodlands is expected to have a higher ecological value.

4.4 Factor Analysis Results of Landscape Metrics

Factor Analysis is performed on calculated metrics and various kinds of landuse compositions to reduce data dimensions separately. The orthogonal factors generated would be more interpretable than the raw data.

For calculated patch metrics, correlation matrix is generated and listed in Table 4.4. Patch metrics of Area, Perimeter and Radius of Gyration are highly and positively correlated (>0.9) with each other. It implies that Perimeter and Radius of Gyration are highly dependent on patch size. Shape index also exhibits a high positive correlation with Fractal Dimension (0.92) and Perimeter (0.80). Contiguity index seems to be a reciprocal of Perimeter-to-Area Ratio, P/A ratio, virtually (correlation=-0.999). These high correlations suggest that these metrics contain redundant information.

Table 4.4. Correlation matrix among calculated patch level metrics

	Area	Perimeter	Radius of Gyration	P/A ratio	Shape	Fractal Dimension	Circle	Contiguity
Area	1.000	0.905	0.909	0.590	0.509	0.211[b]	0.028[c]	0.594
Perimeter	0.905	1.000	0.942	0.359	0.801	0.538	0.273	0.360
Radius of Gyration	0.909	0.942	1.000	-0.453	0.718	0.449	0.325	0.454
P/A ratio	-0.590	-0.359	-0.453	1.000	0.138[a]	0.441	0.411	-0.999
Shape	0.509	0.801	0.718	0.138[a]	1.000	0.921	0.577	-0.140[d]
Fractal Dimension	0.211[b]	0.538	0.449	0.441	0.921	1.000	0.664	-0.444
Circle	0.028[c]	0.273	0.325	0.411	0.577	0.664	1.000	-0.420
Contiguity	0.594	0.360	0.454	-0.999	-0.140[d]	-0.444	-0.420	1.000

The significant levels (1-tailed) are all lower than 0.05, except

a at significant level 0.162

b at significant level 0.065

c at significant level 0.420

d at significant level 0.159

Two independent factors for these metrics are extracted, by Principal Axis Factoring, based on the correlation matrix and after varimax rotation. A rule of thumb of retaining these factors is that the associated eigen value is greater than one. The factor scores for each woodland are listed in Appendix 1. As listed in Table 4.5, they can explain totally 87.59% of data variance.

Table 4.5 Total variance explained by extracted factors for landscape metrics

Factor	% of Variance	Cumulative %
1	48.742	48.742
2	38.846	87.588

The communalities extracted by the factors for each metrics are listed in Table 4.6. Except for Related Circumscribing Circle, whose variance is only extracted by 47.6%, other metrics' variance is extracted by more than 85%.

Table 4.6. Communalities extracted by

Principal Axis Factoring for landscape metrics

	Initial	Extraction
Area	0.976	0.868
Perimeter	0.987	0.961
Radius of Gyration	0.962	0.954
P/A ratio	0.999	0.937
Shape	0.991	0.951
Fractal Dimension	0.978	0.911
Circle	0.731	0.476
Contiguity	0.999	0.950

From the rotated factor matrix in Table 4.7, for factor 1, very high loadings (>0.9) are observed in metrics of Area, Perimeter and Radius of Gyration. Obviously, it can be termed as a size-related factor. P/A ratio exhibits a significant negative loading (0.687) in factor 1 due to its inborn inverse relationship with Area while Contiguity Index, as a reciprocal of P/A ratio, shows a similar positive loading (0.691) in factor 1. Shape Index, as an index of measuring patch shape complexity, also shows a significant loading (0.559) in factor 1. For metrics of Fractal Dimension and Related Circumscribing Circle, they show insignificant loadings in it.

For factor 2, Fractal Dimension shows a highest loading (0.924) in it and followed by Shape index (0.799). P/A ratio and Related Circumscribing Circle exhibit similar and significant positive loadings (0.68 and 0.69 respectively) while Contiguity index shows a similar negative loading in factor 2. In factor 2, metrics of Area, Perimeter and Radius of Gyration show insignificant loadings in it. Therefore, factor 2 can be termed as shape-related factor

Table 4.7. Rotated Factor Matrix for landscape metrics

	Factor 1	Factor 2
Area	0.931	0.017
Perimeter	0.912	0.358
Radius of Gyration	0.937	0.277
P/A ratio	-0.687	0.682
Shape	0.559	0.799
Fractal Dimension	0.239	0.924
Circle	0.068	0.687
Contiguity	0.691	-0.688

4.5 Summary

In this chapter, patch characteristics, i.e. size and shape, of identified Feng Shui woodlands are quantified in terms of landscape metrics. From interpretation of these metrics, identified Feng Shui woodlands are generally found of small size, with a mean patch size of 1.9 hectares, and characterized with shape close to small deciduous forest (Krummel *et al.*, 1987), with mean Fractal Dimension value 1.23.

Factor analysis is performed to reduce data dimensions among the calculated metrics. Two orthogonal factors are extracted and represent size and shape of Feng Shui woodlands accordingly. It implies that redundancy still exists among these sets of metrics. From the extracted factor metrics, area and fractal dimension are two best representative metrics measuring patch characteristics of Feng Shui woodlands.

Chapter 5 Results and Discussion (II)—Interaction between Landuse Composition and Feng Shui woodlands

5.1 Introduction

In this chapter, landuse composition is estimated as percentages of various kinds of landuses across a distance of 500 meters measured from the center of each cardinal patch of identified woodlands. Correlation and clustering analysis are performed to investigate interaction between the estimated landuse composition and physical characteristics of Feng Shui woodlands in order to look into whether there is any possible landuse impact on Feng Shui woodlands.

5.2 Estimation of Landuse Composition

The landuse is categorized into five categories, 1) Built-up area; 2) Vegetation; 3) Village; 4) Water Body; and 5) Feng Shui woodlands. Percentage of each kind of landuses is estimated across 500 meter measured from centre of each woodland patch.

Figure 5.1 shows mean statistics of the percentage of each kind of landuses across 500 meter. Both built-up and vegetation landuses nearly equally dominate the landuse composition and their average percentages keep relatively constant across five hundred meter. Mean percentage of built-up area ranges from 41.1% (in 50 m) to 43.8% (in 500 m) and that of vegetation varies from 39.3% (in 50 m) to 47.1% (in 500 m). A bit lower in percentage of both kinds of landuses within 100 meter is due to the relative significance of size of village and surrounding Feng Shui woodlands in proximity of the studied woodlands. It implies that the landuse composition is relatively homogeneous across 500 meter, i.e. co-dominated by built-up area and vegetation.

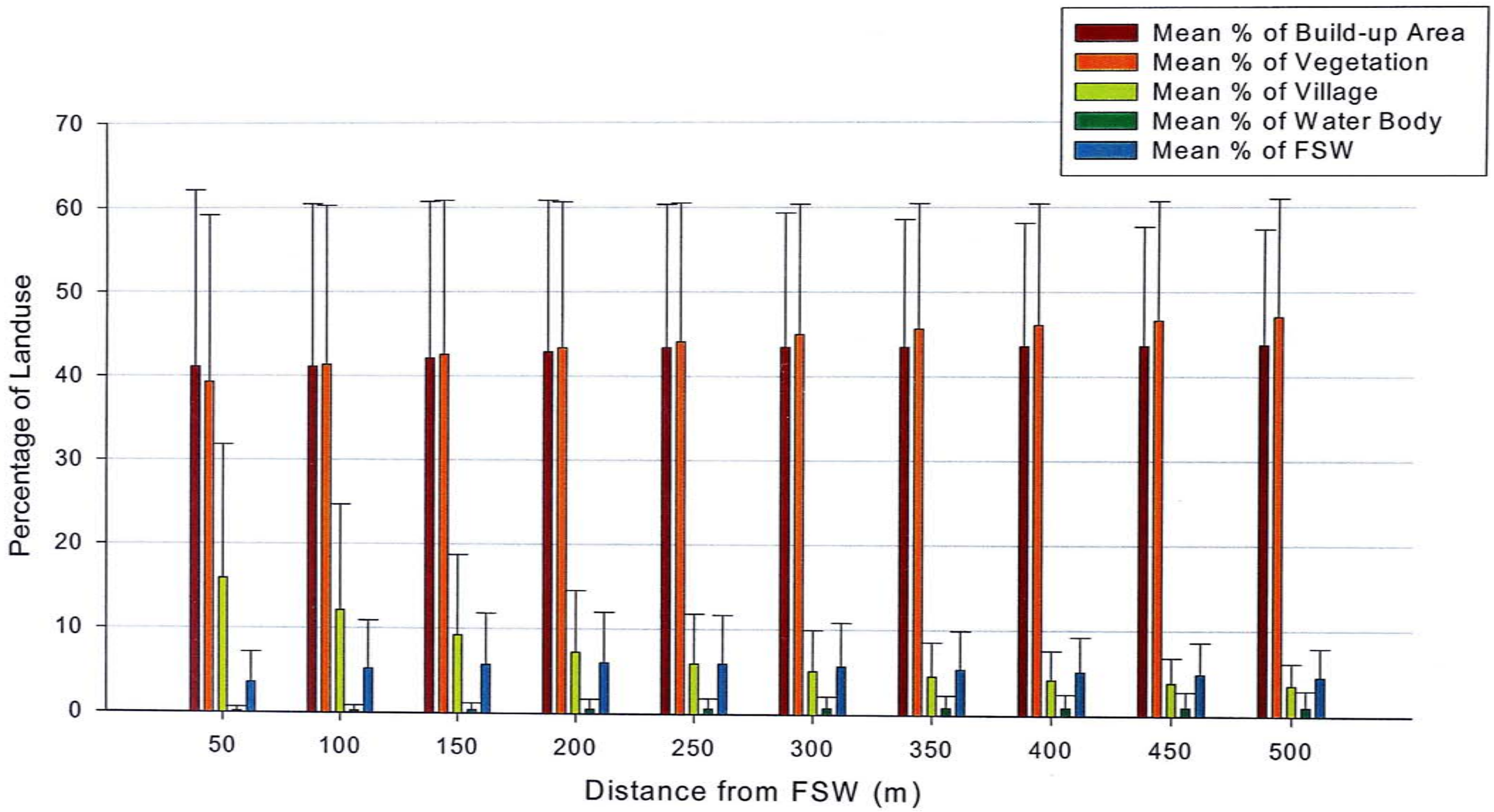


Figure 5.1 Mean Percentage of Landuse near Feng Shui Woodlands across 500 meters

Built-up area includes any concrete-like structure involved in anthropogenic activities, including roads, residential and industrial area and open storage area. This kind of landuse would definitely deteriorate the quality of woodlands, especially at the interface by means of increased trespassing and access as well as industrial and constructional activities. The woodlands surrounded by intense built-up area, such as So Kwun Po (mean % of built-up area is 76.4%) and Ng Uk Tsuen (mean % of built-up area is 74.4%) would be subject to greater developmental threats and other human disturbance.

Vegetation landuse, including farmlands, grassland and other non-Feng Shui woodlands, serves Feng Shui woodlands as a kind of buffer buffering any anthropogenic disturbance on Feng Shui woodlands. Thus, the woodlands surrounded by a large proportion of green vegetation in proximity, such as those lying behind Ha Shan Kai Wat and Cheung Lek (% of vegetation is 92.5% in 50 meter and 81.3% in 100 meter, and is 81.8% in 50 meter and 79.4% in 100 meter respectively.), would be expected to suffer less from human disturbance, and thus have higher quality. In addition, a higher vegetation proportion makes the associated landscape greener and more attractive.

Mean percentage of village decreases from 15.9% in 50 meter to 3.6% in 500 meter. The initial relatively high percentage indicates that, as discussed before, the village area is significant within 100 meter (12-15%) and the decrease reflects the fact that the villages are quite isolated from each other and are scattered throughout the study site. In addition, since Feng Shui woodlands bless for prosperity of the villages and the villagers in turn preserve the woodlands for their fortune, an association would exist between the quality of Feng Shui woodlands and the villages.

Percentage of nearby Feng Shui woodlands increases from 3.6% in 50 meter to 6% in 200 meter and then decreases to 4.6 % in 500 meter. This change suggests that, similar to the distribution pattern of villages, Feng Shui woodlands are scattered throughout the study site by an average distance of 200 meter. Also, a high portion of Feng Shui woodlands nearby would enrich ecological as well as scenic value of the associated landscape.

Average percentage of water body remains at a very low level (0.1-1%) across 500 meter. In fact, only 5 villages are detected to possess water body within 50 meter measured from the woodland patch behind. It is not a good phenomenon from the Feng Shui viewpoint since water (*shui*) is important in Feng Shui in the sense that it brings *Shengqi* (life-force) and prosperity to people (Fan, 1992). When water is scarce, *Shengqi* and prosperity would disperse. Water body is a scarce feature in the study site mainly because development and constructional activities filling up the ponds. In addition, channelization of the rivers, such as Sheung Yue River, alters the spectral characteristics of these rivers to the extent that it becomes similar to other concrete infrastructure, which would be mis-recognized as built-up landuse during image classification.

5.3 Change of Landuse Composition in Feng Shui Woodlands' Neighbourhood

Change of landuse composition for each identified woodlands' neighbourhood are shown in Appendix 2. From those graphs, some points can be observed. Firstly, both landuses of built-up area and vegetation are, on average, almost equally dominant compared with the other three types of landuses. Secondly, for the majority of villages, their change of landuse curves reach plateau at distance between 300 meter and 400 meter. It can be explained by the fact that because both built-up area and vegetation landuses co-dominate the study area while landuses of villages, Feng Shui woodlands and water body, if any, are found localized within the village boundary. When the buffer area increases in size (>300 m), sizes of villages, Feng Shui woodlands and water body becomes insignificant and at this time, these three kinds of landuses reaches equilibrium with a low percentage (< 10%). Thirdly, large villages, such as Fanling Wai and Kam Tsin, are characterized by high percentages of village (76.4% and 49.2% for Fanling Wai and Kam Tsin respectively) in close proximity (within 100 meter). However, small cardinal woodland patch would introduce a bias of causing a high village percentage in near neighbourhood, such as the case in Hung Leng.

Among these landuse change curves, observed at 300 meter, as listed in Table 5.1, according to the dominated landuse type, they can simply be grouped into three types. The first group has the landuse composition dominated by built-up area, defined as % of built-up is at least 10% higher than that of vegetation at 300 meter. There are 19 woodlands found in this group. For instance, Fanling Lau, Fanling Wai, Ling Shan Tsuen and Ko Po Feng Shui woodlands are surrounded intensively by built-up area (as high as 70%). They are often located near the new towns (Fanling & Sheung Shui) and the trunk roads such as Fanling Highway and Sha Tau Kok Road, as well as Ping Che and Ta Kwu Ling where industrial activities are found within the neighbourhood. Besides tolerating a greater development pressure, these woodlands would also have a higher possibility of suffering a greater anthropogenic harms such as increased human access and trespassing as well as other industrial activities, which would be especially greater for peripheral species on the interface (edge effect). Human disturbances may induce fragmentation to these woodland patches, which in turn would decrease the patch size, reduce inter-patch species dispersal and finally lower species diversity in woodlands.

Table 5.1 Landuse Percentages at 300 meter and dominated landuse (in 300 m) for each identified woodlands

Feng Shui woodlands	Landuse Percentage at 300 meter (%)					Dominated Landuse (in 300 m)*
	Built-up	Vegetation	Village	Water Body	FSW	
Chau Tau Tsuen	38.854	50.019	5.483	0.692	4.952	Veg
Chau Tau Tsuen_2	25.146	49.318	8.153	0.601	16.783	Veg
Cheung Lek	22.066	72.452	3.550	0.952	0.980	Veg
Fanling Lau	73.310	15.613	8.071	0.000	3.006	Built
Fanling Wai	57.574	17.758	18.210	0.867	5.591	Built
Ha Shan Kai Wat	18.201	74.418	2.510	0.000	4.871	Veg
Hang Tau	30.360	53.190	13.752	0.826	1.872	Veg
Hang Tau Tai Po	38.131	33.634	25.484	1.506	1.245	Co
Ho Sheung Heung	56.203	30.690	7.717	3.381	2.009	Built
Hung Kiu San Tsuen	61.851	34.522	2.170	1.300	0.157	Built
Hung Leng	62.611	23.368	12.147	1.454	0.419	Built
Kam Tsin	39.667	51.248	8.425	0.399	0.261	Veg
Ko Po	57.883	32.720	1.994	1.290	6.113	Built
Lei Uk	41.951	46.583	4.675	0.000	6.791	Co
Lin Tong Mei	46.246	48.212	4.023	0.738	0.781	Co
Ling Shan Tsuen	63.012	29.941	3.987	0.783	2.277	Built

Feng Shui woodlands	Landuse Percentage at 300 meter (%)					Dominated Landuse (in 300 m)*
	Built-up	Vegetation	Village	Water Body	FSW	
Liu Pok	18.222	69.138	4.869	6.583	1.188	Veg
Lo Wai	16.074	55.157	11.582	0.000	17.187	Veg
Ma Tso Lung San Tsuen	30.320	65.961	2.855	0.310	0.554	Veg
Ma Tso Lung Shun Yee San Tsuen	25.763	66.567	3.905	3.487	0.278	Veg
Ma Wat Wai	40.757	37.271	14.202	0.000	7.770	Co
Ng Uk Tsuen	74.167	24.052	1.781	0.000	0.000	Built
Ping Che	54.082	30.603	3.968	0.433	10.914	Built
Ping Che Kak Tin	46.969	46.671	3.807	0.459	2.093	Co
Ping Che New Village	54.227	32.742	4.568	0.247	8.215	Built
Ping Kong	33.043	60.101	6.397	0.000	0.460	Veg
Pun Uk Tsuen	29.667	55.552	6.673	0.818	7.291	Veg
San Tong Po	41.308	39.891	2.633	0.573	15.595	Co
Sheung Shan Kai Wat	20.720	66.826	3.057	0.223	9.175	Veg
Sheung Shan Kai Wat_2	24.171	63.065	5.199	0.000	7.564	Veg
Siu Hang San Tsuen	28.939	65.161	4.140	1.478	0.283	Veg
So Kwun Po	78.227	19.145	1.216	0.645	0.767	Built
Tai Po Tin	41.842	53.196	2.677	0.000	2.284	Veg
Tsung Pak Long	47.669	44.377	6.030	0.540	1.384	Co

Feng Shui woodlands	Landuse Percentage at 300 meter (%)					Dominated Landuse (in 300 m)*
	Built-up	Vegetation	Village	Water Body	FSW	
Tsung Yuen	32.009	49.525	7.113	6.263	5.090	Veg
Tsz Tong Tsuen	16.687	67.192	7.444	0.000	8.678	Veg
Wo Hop Shek	35.518	55.175	6.541	0.000	2.765	Veg
Wo Hop Shek 2	39.007	43.928	8.379	0.494	8.193	Co
Woods 1	44.939	44.067	3.326	0.015	7.653	Co
Woods 2	59.374	31.505	2.129	0.208	6.784	Built
Woods 3	45.265	53.400	1.073	0.196	0.065	Co
Woods 4	17.721	73.194	3.251	0.000	5.834	Veg
Woods 5	42.066	48.423	0.923	0.196	8.392	Co
Woods 6	47.444	36.052	1.465	0.000	15.039	Built
Woods 7	54.456	29.477	0.000	0.000	16.067	Built
Woods 8	53.376	30.728	0.000	0.000	15.895	Built
Woods 9	58.198	28.003	0.000	0.000	13.799	Built
Woods 10	67.440	28.828	0.000	0.639	3.093	Built
Woods 11	48.844	48.550	0.000	0.000	2.606	Co
Woods 12	52.153	35.630	0.584	0.000	11.633	Built
Woods 13	44.116	43.125	2.443	0.000	10.317	Co
Woods 14	49.011	41.524	2.149	0.000	7.317	Co

Feng Shui woodlands	Landuse Percentage at 300 meter (%)					Dominated Landuse (in 300 m)*
	Built-up	Vegetation	Village	Water Body	FSW	
Yin Kong	56.442	35.439	5.151	2.390	0.578	Built

* Veg=Vegetation dominated
Built=Built-up area dominated
Co=Co-dominated by built-up area and vegetation

The second group includes the woodlands behind Chau Tau Tsuen, Hang Tau, Ha Shan Kai Wat and Tsz Tong Tsuen which are surrounded by a large proportion of vegetation area (% of vegetation is at least 10% higher than that of built-up area at 300 meter). Twenty out of fifty three woodlands belong to this group. Vegetation cover such as grassland and farmland, especially those near the Feng Shui woodlands, would cushion the human impact on Feng Shui woodlands by means of, firstly, directly providing a physical green area or buffering distance, which exert virtually no negative impact on the woodlands themselves, to “absorb” the anthropogenic disturbance. Secondly, they offer a developmental priority over Feng Shui woodlands when various developmental options are under consideration.

Fourteen woodlands belong to the third group which shows the woodlands in which the proportional distribution of landuses of built-up area and vegetation are similar (the difference is less than 10%), at 300 meter. Ma Wat Wai and San Tong Po Feng Shui woodlands are some examples. Due to the relative insignificance of other three types of landuses, percentages of built-up area and vegetation converge at about 40%. For these woodlands, the nature of landuse impact on Feng Shui woodlands would depend on the intensity of vegetation landuse in proximity. The nearby vegetation covers would essentially buffer the negative landuse impact posed by built-up landuse on the woodlands.

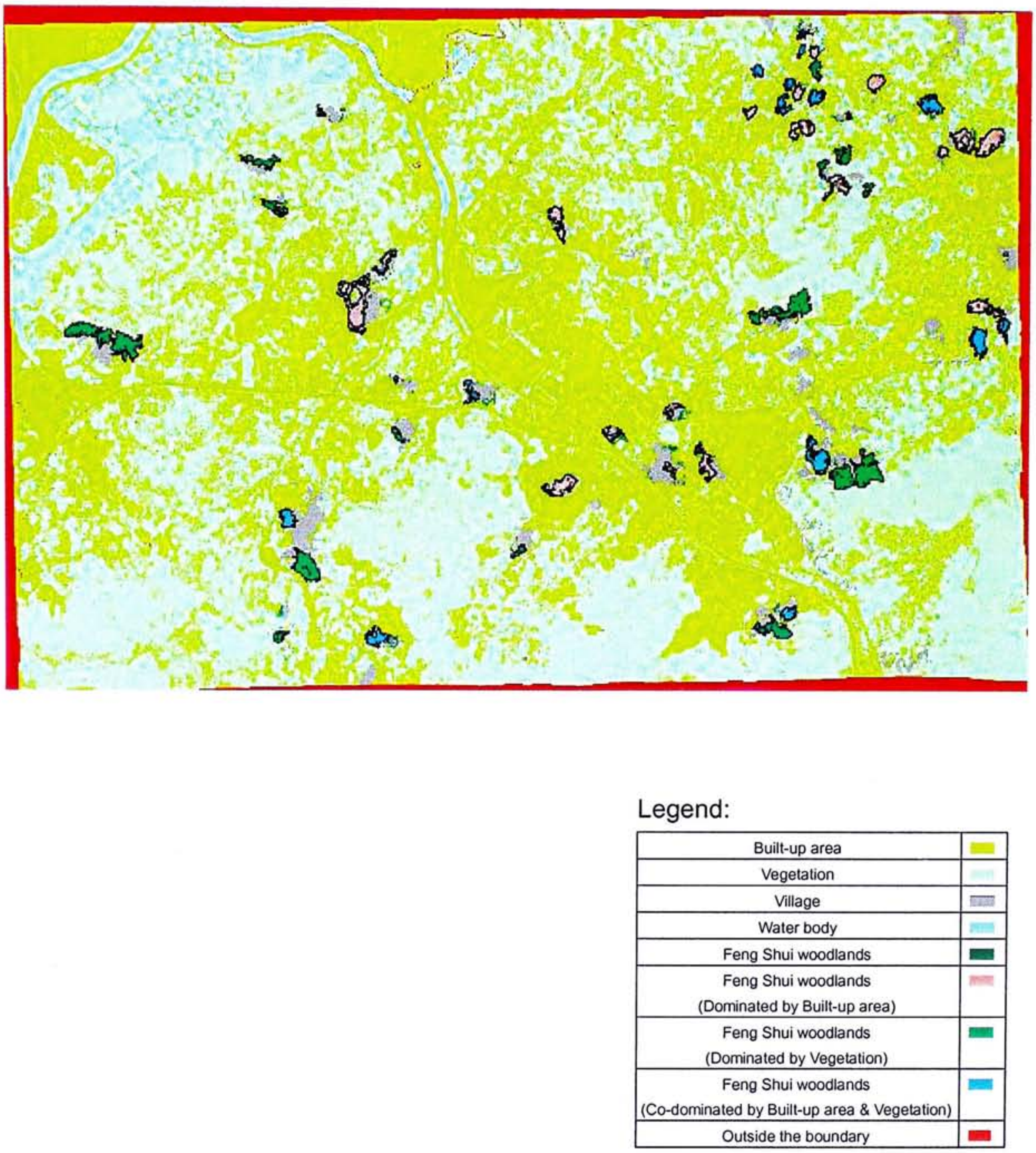


Figure 5.2 Spatial Distribution of Feng Shui woodlands according to types of dominated landuses

5.4 Factor Analysis of Landuse Composition

Landuse composition, except percentage of water body due to its negligible value, within 100 meter, 300 meter and 500 meter of each woodland patch is used as input for a factor analysis so as to extract independent factor(s) which would be more interpretable.

From the correlation matrix in Table 5.2, strong positive correlations are found among the percentages of landuse of the same kind in various distances. For example, correlation between percentages of built-up area in 300 meter and in 500 meter is 0.956 and that between percentages of vegetation in 100 meter and in 300 meter is 0.904. This suggests that the landuse composition in the study site is quite monotonous and predictable. Another point observed is that the percentages of vegetation show a strong negative correlation with those of built-up area and vice versa. It is because the landscape is either dominated by built-up area or vegetation, or equally dominated.

Table 5.2 Correlation matrix among estimated landuse percentage

	% of Built-up area(100m)	% of Vegetation (100m)	% of Village (100m)	% of FSW (100m)	% of Built-up area(300m)	% of Vegetation (300m)	% of Village (300m)	% of FSW (300m)	% of Built-up area(500m)	% of Vegetation (500m)	% of Village (500m)	% of FSW (500m)
% of Built-up area(100m)	1.000	-0.754	-0.358	-0.101[c]	0.885	-0.764	-0.335	-0.066[d]	0.786	-0.720	-0.143[b]	0.066[d]
% of Vegetation (100m)	-0.754	1.000	-0.279	-0.140[b]	-0.831	0.904	-0.193[a]	-0.001[e]	-0.812	0.825	-0.290	-0.021[e]
% of Village (100m)	-0.358	-0.279	1.000	-0.077[c]	-0.068[d]	-0.123[b]	0.806	-0.240	0.047[d]	-0.116[c]	0.660	-0.321
% of FSW (100m)	-0.101[c]	-0.140[b]	-0.077[c]	1.000	-0.092[c]	-0.132[b]	-0.036[d]	0.775	-0.072[d]	-0.031[e]	-0.040[d]	0.566
% of Built-up area(300m)	0.885	-0.831	-0.068[d]	-0.092[c]	1.000	-0.914	-0.191[a]	-0.121[b]	0.956	-0.902	-0.016[e]	-0.003[e]
% of Vegetation (300m)	-0.764	0.904	-0.123[b]	-0.132[b]	-0.914	1.000	-0.082[c]	-0.135[b]	-0.913	0.949	-0.216[a]	-0.174[b]
% of Village (300m)	-0.335	-0.193[a]	0.806	-0.036[d]	-0.191[a]	-0.082[c]	1.000	-0.148[b]	-0.111[c]	-0.016[e]	0.865	-0.226[a]
% of FSW (300m)	-0.066[d]	-0.001[e]	-0.240	0.775	-0.121[b]	-0.135[b]	-0.148[b]	1.000	-0.073[d]	-0.066[d]	-0.137[b]	0.835
% of Built-up area(500m)	0.786	-0.812	0.047[d]	-0.072[d]	0.956	-0.913	-0.111[c]	-0.073[d]	1.000	-0.962	0.074[c]	-0.009[e]
% of Vegetation (500m)	-0.720	0.825	-0.116[c]	-0.031[e]	-0.902	0.949	-0.016[e]	-0.066[d]	-0.962	1.000	-0.216[a]	-0.150[b]
% of Village (500m)	-0.143[b]	-0.290	0.660	-0.040[d]	-0.016[e]	-0.216[a]	0.865	-0.137[b]	0.074[c]	-0.216[a]	1.000	-0.195[a]
% of FSW (500m)	0.066[d]	-0.021[e]	-0.321	0.566	-0.003[e]	-0.174[b]	-0.226[a]	0.835	-0.009[e]	-0.150[b]	-0.195[a]	1.000

The significant levels (1-tailed) are all lower than 0.05, except

a at significant level > 0.05 and ≤ 0.10;
b at significant level > 0.10 and ≤ 0.20;
c at significant level > 0.20 and ≤ 0.30;
d at significant level > 0.30 and ≤ 0.40;
e at significant level > 0.40 and ≤ 0.50.

Three orthogonal factors are extracted based on their correlation matrix by Principal Component Analysis after varimax rotation. The factor scores for each woodland are listed in Appendix 1. As listed in Table 5.3, these factors can explain totally 88.9% of data variance.

Table 5.3 Total variance explained by extracted factors for landuse composition

	% of Variance	Cumulative %
Factor 1	44.346	44.346
Factor 2	23.528	67.874
Factor 3	21.035	88.908

From Table 5.4, except for percentages of Feng Shui woodlands in 100 meter and 500 meter, the extracted factors can explain more than 80% of individual data variance.

Table 5.4 Communalities extracted by

Principal Component Analysis for landuse composition

	Initial	Extraction
% of Built-up area(100m)	1.000	0.885
% of Vegetation (100m)	1.000	0.894
% of Village (100m)	1.000	0.825
% of FSW (100m)	1.000	0.762
% of Built-up area(300m)	1.000	0.982
% of Vegetation (300m)	1.000	0.977
% of Village (300m)	1.000	0.929
% of FSW (300m)	1.000	0.934
% of Built-up area(500m)	1.000	0.939
% of Vegetation (500m)	1.000	0.927
% of Village (500m)	1.000	0.815
% of FSW (500m)	1.000	0.799

From the rotated factor matrix in Table 5.5, for factor 1, high positive loadings are observed in percentages of built-up area in 100 meter, 300 meter and 500 meter (0.873, 0.977 and 0.966 respectively) and high negative loadings are found in percentages of vegetation cover in all studied distances (-0.903, -0.963, -0.952 for 100 meter, 300 meter and 500 meter respectively) while other percentages of landuses show insignificant loadings on it. This factor can represent a ratio of proportion of built-up area to proportion of vegetation cover in the studied area, i.e. $\frac{\%ofBuiltup}{\%ofVegetation}$.

Table 5.5 Rotated Factor Matrix for landuse composition

	Factor 1	Factor 2	Factor 3
% of Built-up area(100m)	0.873	-0.341	-8.280E-02
% of Vegetation (100m)	-0.903	-0.269	-7.080E-02
% of Village (100m)	1.909E-02	0.895	-0.153
% of FSW (100m)	-6.770E-03	5.196E-02	0.871
% of Built-up area(300m)	0.977	-0.129	-0.107
% of Vegetation (300m)	-0.963	-0.148	-0.166
% of Village (300m)	-6.920E-02	0.960	-5.450E-02
% of FSW (300m)	-2.070E-02	-0.103	0.961
% of Built-up area(500m)	0.966	-1.900E-02	-7.280E-02
% of Vegetation (500m)	-0.952	-0.113	-9.080E-02
% of Village (500m)	0.110	0.895	-4.840E-02
% of FSW (500m)	6.570E-02	-0.214	0.865

The second factor can explain the proportion of village area among the studied distances since significant loadings are observed in percentage of village in 100 meter, 300 meter and 500 meter (0.895, 0.960 and 0.895 respectively) while other types of landuses show insignificant loadings in it.

For factor 3, significant loadings are observed in percentages of Feng Shui woodlands in studied distances (0.871, 0.961 and 0.865 for 100 meter, 300 meter and 500 meter respectively) while other landuses show insignificant loadings in it. Thus, it represents a proportion of Feng Shui woodlands in the study area.

5.5 Interaction Between Landuse Composition and Feng Shui Woodlands

5.5.1 Correlation Analysis

Correlation analysis is adopted to investigate the relationship between patches' neighbour landuse composition and corresponding patches' size and shape, i.e. patch physical characteristics.

Pearson's correlation coefficient is adopted to investigate the relationship between the factors extracted from calculated patch metrics, i.e. patch characteristics, and that from estimated landuse composition. The correlation matrix is listed in Table 5.6. After examining these coefficients, there is no significant correlation found between any pair of the studied factors. Obviously, virtually no correlation exists between the pair of factors related to size and shape, or between any pairs of factors representing percentage of landuse since they are orthogonal to each other. The highest negative correlation, but not significant, is observed between the pair of proportion of Feng Shui woodlands nearby and shape of the woodland patch, which is –0.266. For other pairs, no more than 0.1 correlations are found in any pair.

Table 5.6 Pearson correlation matrix

	Size-related	Shape-related	%Built/%Veg	%Village	%FSW
Size-related	1.000	-0.005	-0.042	-0.006	-0.096
Shape-related	-0.005	1.000	0.076	0.095	-0.266
%Built/%Veg	-0.042	0.076	1.000	0.000	0.000
%Village	-0.006	0.095	0.000	1.000	0.000
%FSW	-0.096	-0.266	0.000	0.000	1.000

These results suggest that landuse compositions seem to have no significant impact on the patch characteristics of Feng Shui woodlands. In other words, size and patch of Feng Shui woodlands seem to be insensitive to developmental pressure or industrial activities nearby. This may be because, firstly, Feng Shui woodlands have been preserved by people living in villages associated with. As Feng Shui woodlands, besides their Feng Shui value, provide shading, shielding and other practical functions for villages as stated by Webb (1996), villagers would protect the woodlands and keep them away from felling or any disturbance. In addition, since there are not many villages open for public access or visit, except those located among the Lung Yeuk Tau Heritage Trail, nor too many people would access the villages or associated Feng Shui woodlands, trespassing impact on Feng Shui woodlands would thus be considered as minimal or insignificant.

Moreover, many identified woodlands, e.g., Ho Sheung Heung, Hang Tau and Hang Tau Tai Po, are fallen into green belt zone. Designation of these woodlands to green belt zone would be responsible to give protection to them, especially for those woodlands without immediately associated villages, e.g., Woods 12, 13 and 14 near Lei Uk. Planning these woodlands to green belt zone is primarily to promote the conservation of the natural environment and to safeguard them from encroachment by urban development. More specifically, they serve 1) to conserve existing landscape features, areas of scenic value and areas of recognised feng shui importance; 2) to define the outer limits of urbanized districts and to serve as a buffer between and within urban areas; and 3) to provide additional outlets for passive recreational uses (Town Planning Board, 2000). Since an application of new development of these areas will only be considered under an exceptional circumstance with very strong planning grounds and only compatible uses such as water works will be permitted, these woodlands are protected against development and preserved to retain their characteristics.

No significant correlation exists between the factor representing $\frac{\%ofBuiltup}{\%ofVegetation}$ and size-related or shape-related factor for Feng Shui woodlands. It implies that the landuse categories adopted in this study may not be detailed enough. The simplified landuse categorization scheme may over-generalize the corresponding landuse impact imposed by various kinds of landuses involved. For example, impact imposed by residential area on the woodlands may not be equal to that imposed by industrial landuse of same size and role of trees played related to Feng Shui woodlands may not be as same as that played by farmlands. A more detailed landuse categorization scheme enables us to look at relationships between impacts of various kinds of landuse and physical characteristics of Feng Shui woodlands clearly and in detail. However, provided by the fact that, in general, built-up area would pose developmental pressure, trespassing impact and other negative impacts on the woodlands as well as vegetation would buffer these impacts, the assumption in this study, which is the proportionality between intensity of landuse impact and its area, would still be valid.

5.5.2 Cluster Analysis

K-means clustering is adopted to classify the identified woodlands into several relatively homogeneous clusters according to the generated factors representing various kinds of landuses and that related to physical characteristics of Feng Shui woodlands. It provides us a classification of Feng Shui woodlands based on various proportions of landuses and physical characteristics of Feng Shui woodlands.

Three clusters are formed and their cluster centres are listed in Table 5.7. The cluster ID and corresponding distance of each woodland patch are listed in Appendix 1. Figures 5.3-5.8 show graphical distributions of various factor scores for three clusters. From Table 5.7, there are 11 woodlands categorized into Cluster 1. As shown in Figure 5.3, Cluster 1 woodlands have negative value of size-related factor score and are distributed evenly across the vertical axis. This means that Cluster 1 includes the woodlands of small size, which are surrounded by nearly equal amount of built-up area and vegetation covers. The woodlands also form a cluster in the positive portion of axis representing percentage of village which means that they are associated with large villages, as shown in Figure 5.4. From Figure 5.5, the negative factor score of percentage of Feng Shui woodlands nearby means that Cluster 1 woodlands are surrounded by small amount of Feng Shui woodlands. From Figures 5.6-5.8, the distribution of factor scores of shape-related factor for Cluster 1 is so large that the woodlands in this group are not as complicated as the cluster centre means. This cluster represents woodlands of less ecological as well as scenic value. For example, as shown in Figure 5.3, Feng Shui woodland of Hung Leng only consists of few trees.

Figure 5.3 Photo showing Feng Shui woodland behind Hung Leng Village

Their small size means they are less capable of carrying rich species and species inside would be easily susceptible to human disturbance. Also, they are surrounded by a low percentage of Feng Shui woodlands and relatively isolated from other woodlands. Thus, they would have less landscape ecological value.

Table 5.7 Final cluster centres

	Cluster		
Factors	1	2	3
SIZE-related	-1.10121	-0.08575	0.83864
SHAPE-related	0.72915	-0.60740	0.42143
%Built-up/%Veg	-0.04810	-0.12150	0.20981
%Village	0.90105	-0.41788	0.03150
%FSW	-0.48952	0.65551	-0.64725
Total no. of cases	11	25	17

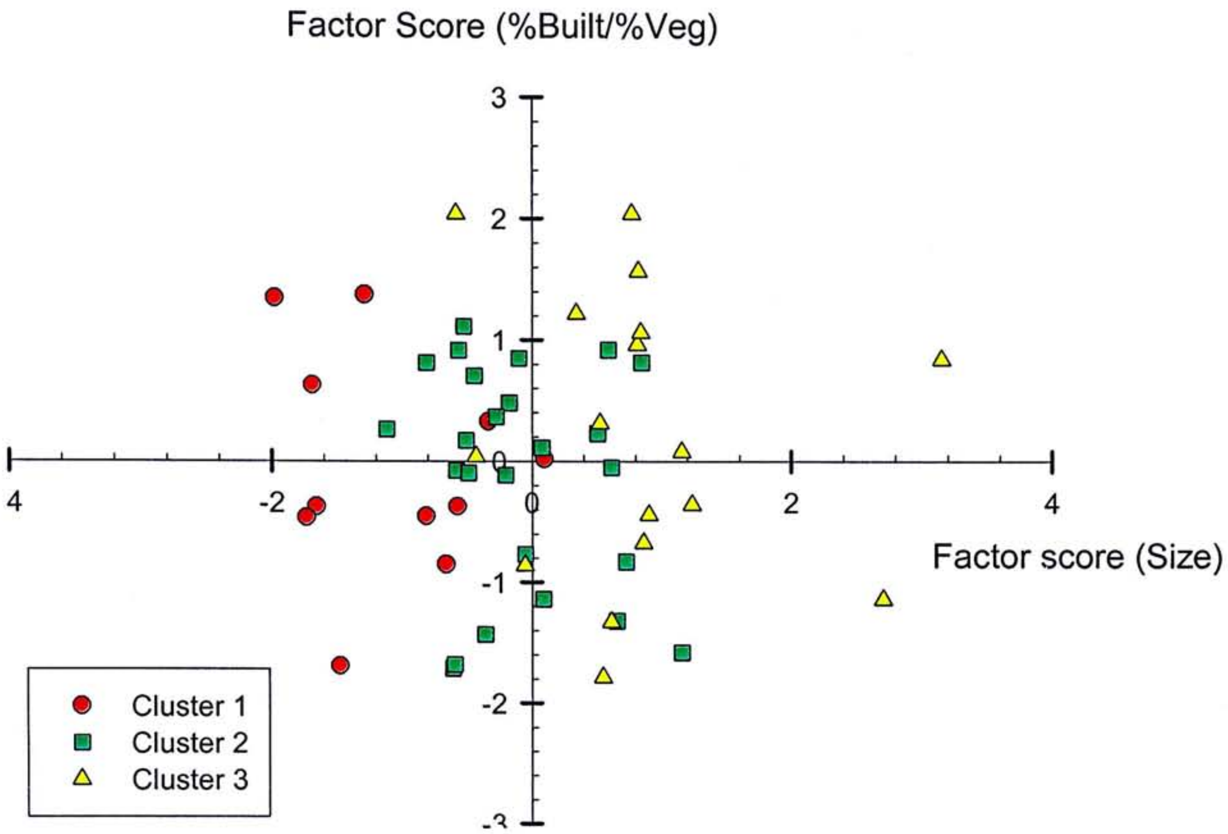


Figure 5.4 Factor Score Distribution of Three Clusters
(% of Built-up/% of Vegetation vs Size)

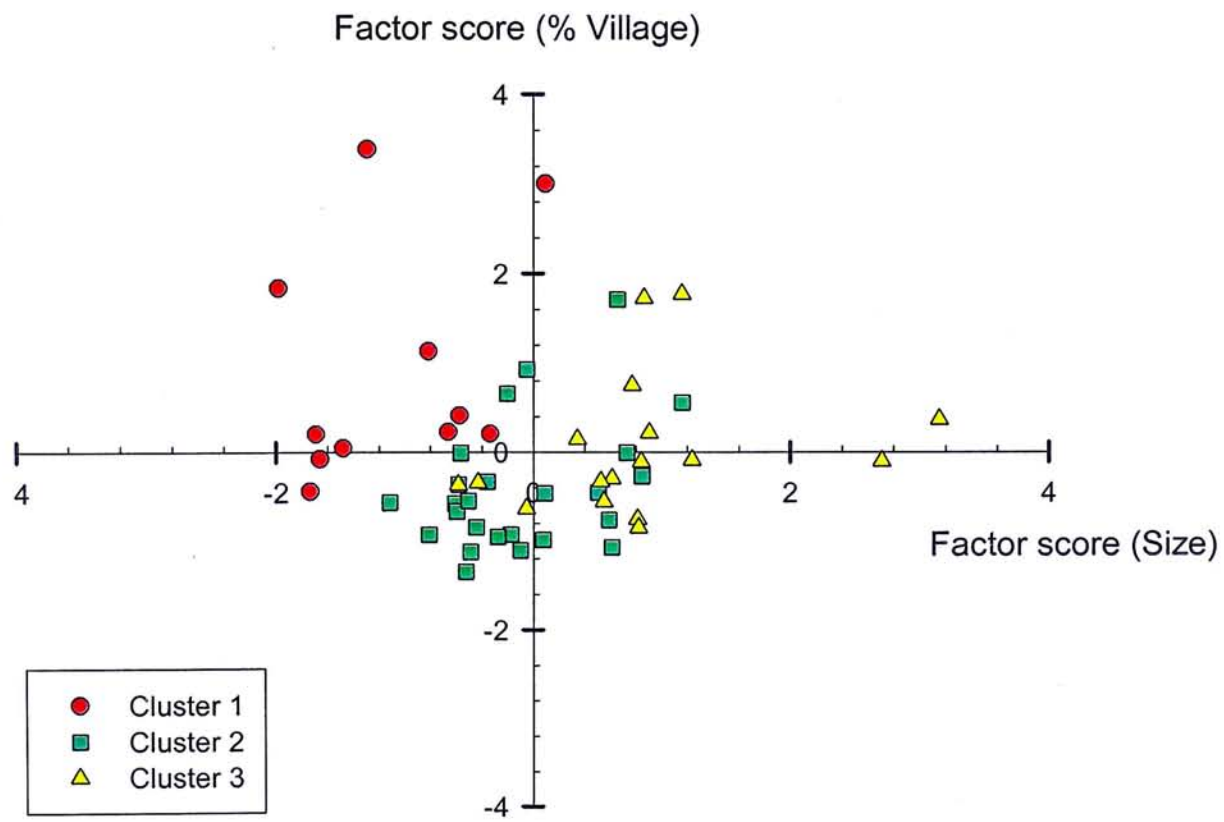


Figure 5.5 Factor Score Distribution of Three Clusters (% of Village vs Size)

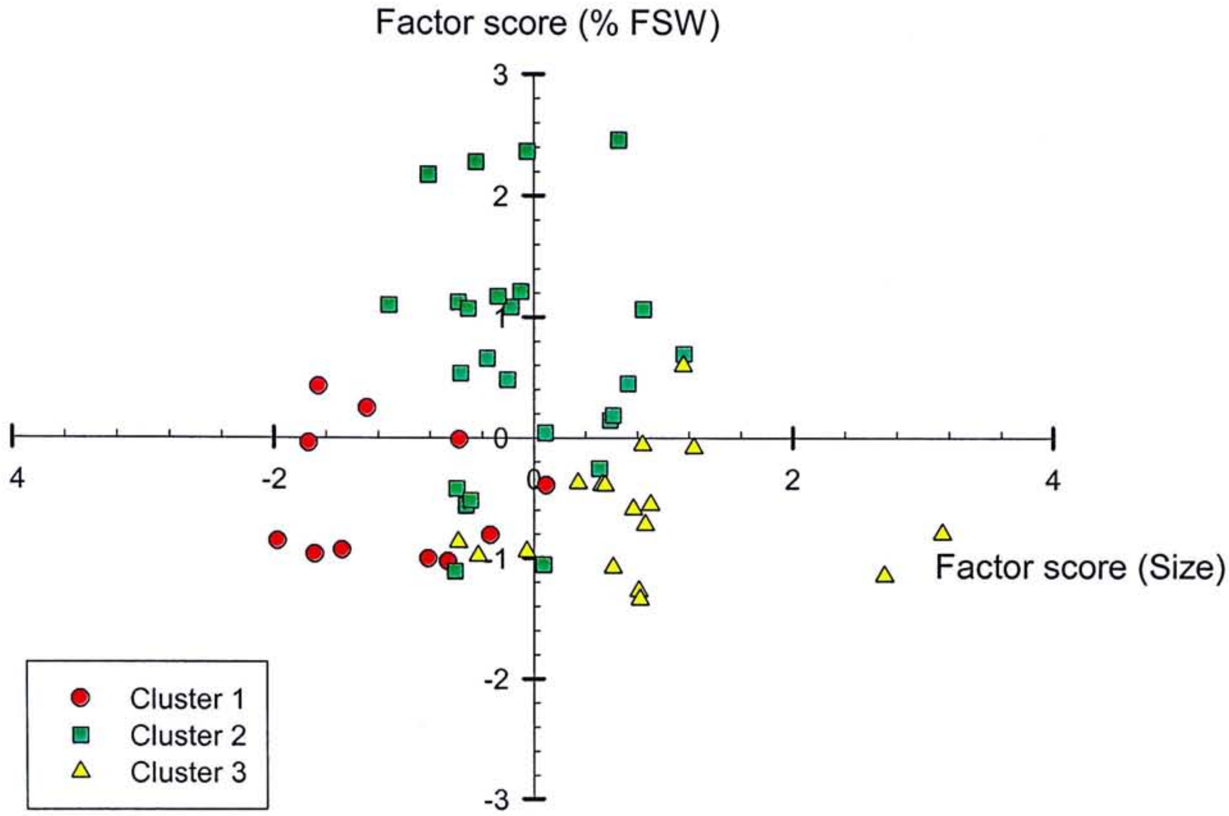


Figure 5.6 Factor Score Distribution of Three Clusters (% of FSW vs Size)

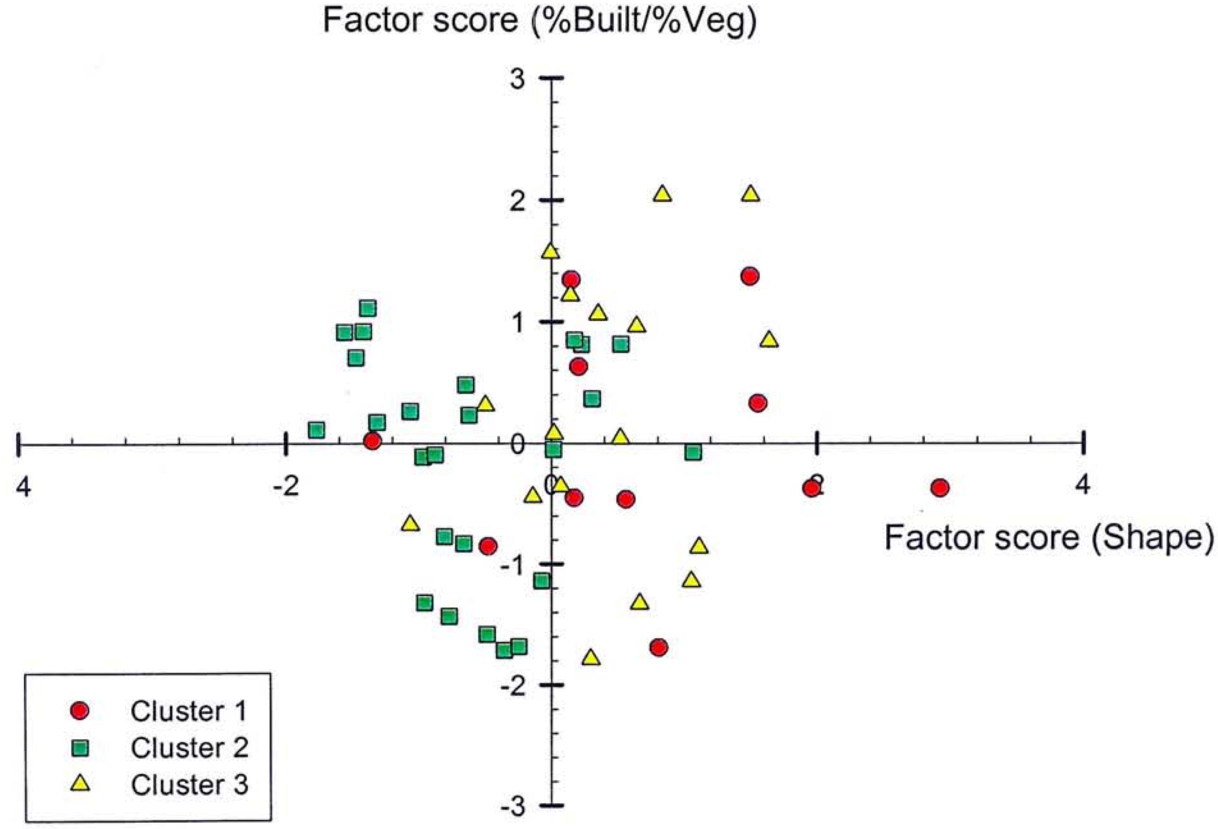


Figure 5.7 Factor Score Distribution of Three Clusters

(% of Built-up/% of Vegetation vs Shape)

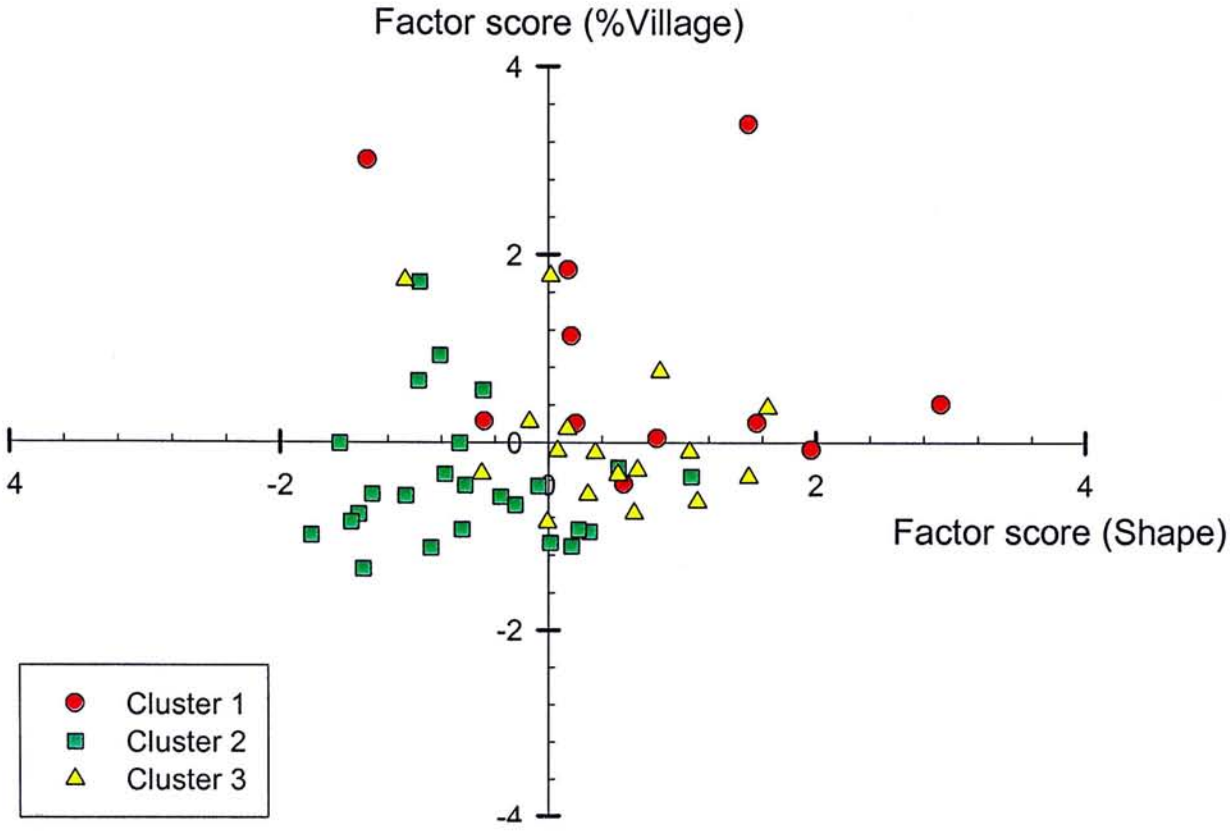


Figure 5.8 Factor Score Distribution of Three Clusters (% of Village vs Shape)

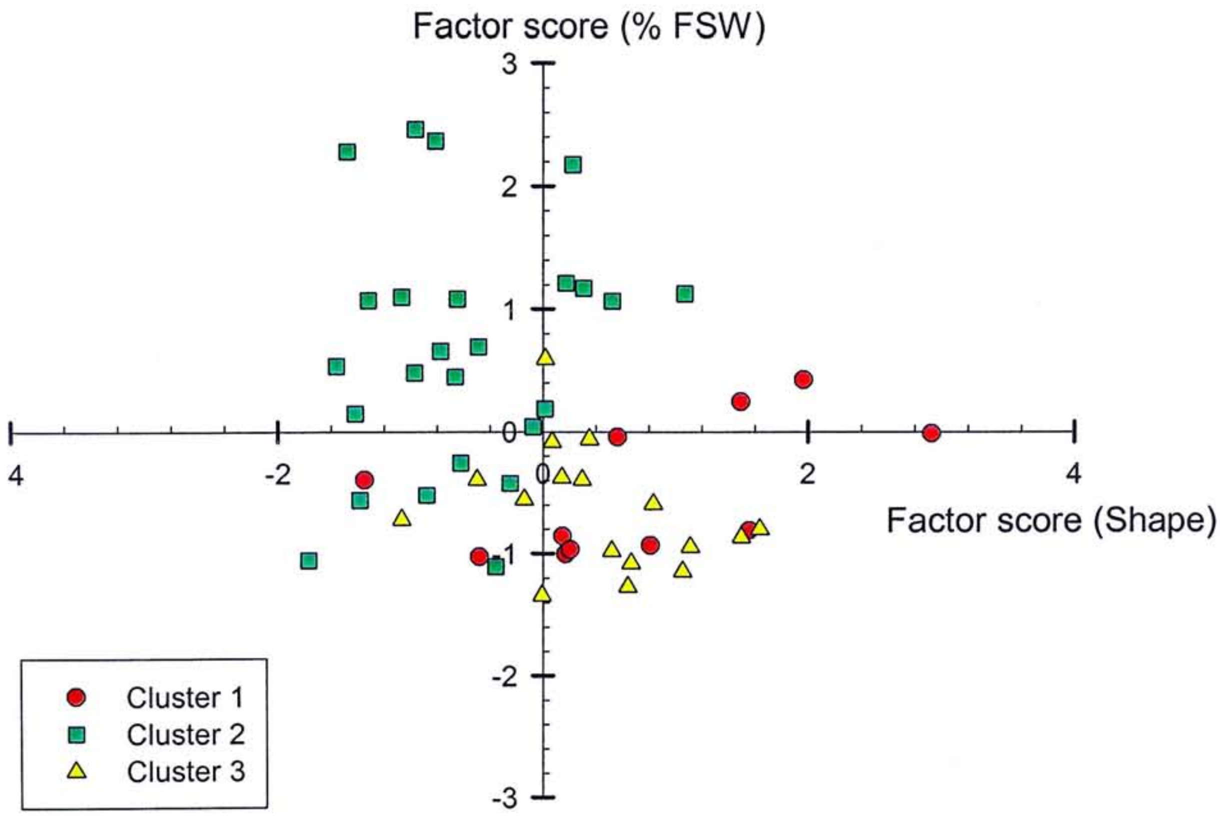


Figure 5.9 Factor Score Distribution of Three Clusters (% of FSW vs Shape)

Cluster 2 is composed of 25 woodlands. As shown in Figure 5.4, the factor score distribution shows that the woodlands of Cluster 2 are of medium size and associated with small or even village. From Figures 5.6 and 5.8, this group of Feng Shui woodlands is simple in shape and surrounded by a considerable amount of vegetation and Feng Shui woodlands nearby. Many of them are those concentrated in northeastern part of the study site, i.e. near Ta Kwu Ling, since woodlands over there are without village immediately behind such as Woods 5 & Woods 6 and are situated closely with each other. Such a simple patch shape is evidence which these woodlands might suffer from human disturbance. However, the landscape of this kind of woodlands would still has a high landscape ecological value due to the green scenic view as well as the relatively compact distribution of Feng Shui woodlands. For example, as shown in Figure 5.10, Lo Wai and Tsz Tong Tsuen Feng Shui woodlands are closely located to each other.

Figure 5.10 Photo showing Feng Shui woodlands behind Ma Wat Wai, Lo Wai and Tsz Tong Tsuen (from left to right)

There are 17 large and complex woodlands grouped into Cluster 3, as indicated by positive factor scores in Figures 5.3 and 5.6. In addition, this group of woodlands is characterized by a relatively high percentage of built-up landuse. From Figure 5.5, a negative factor score means that a very low portion of Feng Shui woodlands is found in its neighbourhood. As shown in Figure 5.4, this kind of woodlands lies behind village of medium size. These woodlands seem to be of higher ecological importance than the other groups since they possess relatively large woodlands size and considerable shape complexity, that mean they probably contain more species and are less disturbed respectively. One of the examples is the Feng Shui woodland behind Hang Tau which is shown in Figure 5.11.

Figure 5.11 Photo showing Feng Shui woodland behind Hang Tau

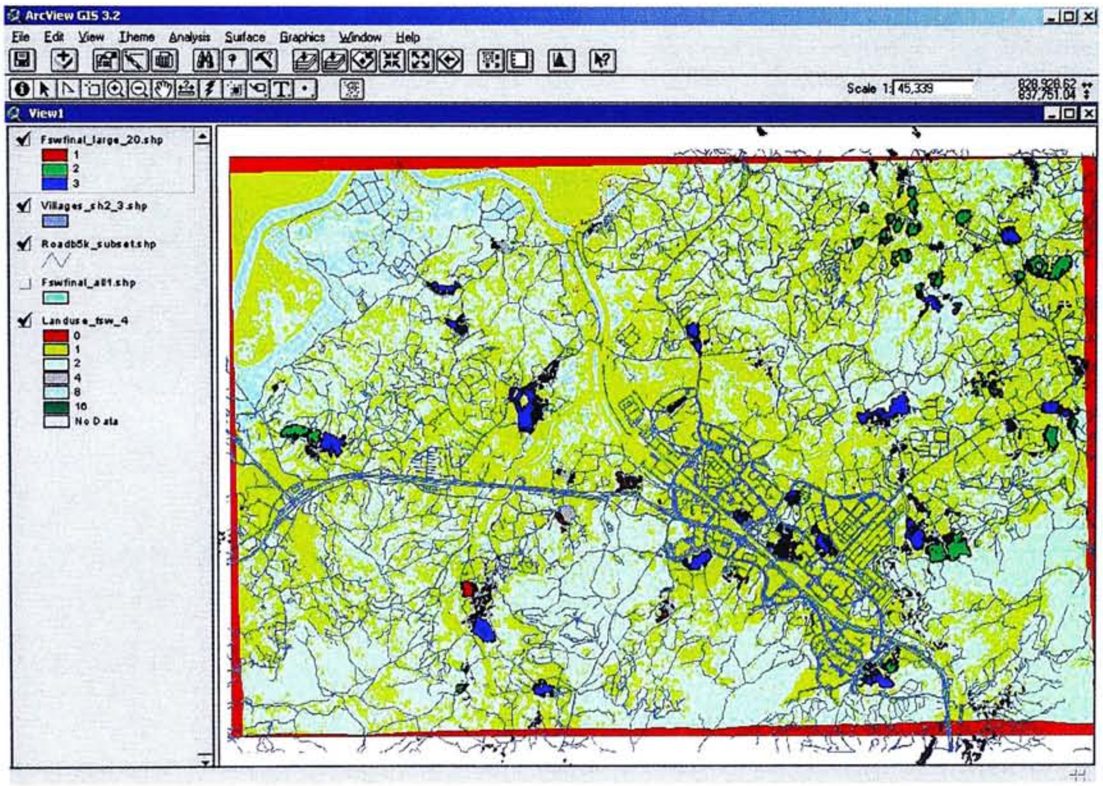
However, the landscape ecological value of this group of woodlands would not be so high since they are quite isolated from other woodlands, and surrounded by relatively high portion of built-up landuse which means that the woodlands of this group might be more vulnerable to urban development.

Compared with the grouping achieved in section 5.3, which is only based on solely the type of dominated landuses in 300 meters measured from the centre of each woodland, the clustering results represented in this section classify the woodlands according to the factors representing various types of landuses and that related to physical patch characteristics of Feng Shui woodlands, that means this clustering take both the patch characteristics of Feng Shui woodlands and the surrounding landuse characteristics into consideration. For instance, Feng Shui woodlands in Chau Tau Tsuen and Fanling Lau belong to Cluster 3, but their surroundings are dominated by vegetation and built-up area respectively.

5.6 GIS Database

A GIS database is constructed to store the calculated patch metrics, estimated landuse composition, the factor scores extracted in factor analysis and cluster ID and corresponding distance generated in clustering analysis. It is helpful in displaying spatial distribution of woodlands of various characteristics such as large patch size, complicated shape or same cluster

ID. Overlaying with the landuse map, it also assists interpretation of clustering results. As shown in Figure 5.9, Cluster 1, in red colour, includes those small woodlands lying behind Kam Tisn and Hung Leng. Green colour represents Cluster 2 which involves medium size woodlands and frequently found in Ta Kwu Ling and Ping Che. Blue one represents those isolated and large Feng Shui woodlands (Cluster 3).



Legend:

Cluster	Colour
1	
2	
3	

Figure 5.12 Spatial Distribution of Clustering Results

5.7 Summary

To summarize, in this chapter, landuse composition, including percentages of built-up area, vegetation cover, village, water body and Feng Shui woodland nearby, of each identified woodland is estimated and interaction between physical characteristics of Feng Shui woodlands and their surrounding landuses is investigated by correlation and clustering analysis. Factor analysis is also performed to reduce the data dimensions of the calculated landuse composition. The rotated factors extracted indicate that the calculated landuse percentages are consistent across 100 meter, 300 meter and 500 meter.

No significant correlation exists between any characteristic of Feng Shui woodlands and their surrounding landuses. The main reasons explaining why landuses pose virtually no impact on Feng shui woodlands are that firstly, the woodlands are preserved by villagers due to their values of various aspects such as Feng Shui and functionality. Secondly, many of the woodlands are planned as green belt zones which protect the woodlands against development.

Totally three clusters are formed by *K-means* clustering. Among these three groups, Clusters 2 seems to be most seductive to green tours due to a green landscape and many Feng Shui woodlands nearby. Cluster 3 includes woodlands of highest landscape ecological importance due to their large woodland size and complex shape. Small and isolated woodlands are found in Cluster 1, which lower their ecological and scenic values.

Chapter 6 Conclusion

6.1 Summary of The Study

To conclude, a landscape approach, with remote sensing and GIS techniques, is used to evaluate landscape ecology of Feng Shui woodlands in this study. A radiometrically and geometrically corrected IKONOS imagery covering the Northeast New Territories is used to extract Feng Shui woodlands and produce the thematic map for landuse composition estimation.

Though GLCM textural data is incorporated into supervised Maximum Likelihood Classification to extract Feng Shui woodlands, Feng Shui woodlands still show no spectral and textural differences with other trees and woodlands. Thus, post-classification sorting, with the aid of topographic map and digital village polygon (G1000), is needed to extract Feng Shui woodlands.

Landscape ecology is evaluated in terms of landscape metrics and landuse composition. Eight patch level landscape metrics are calculated for each identified woodland and five types of landuses are estimated across 500 meters measured from each identified woodland. Factor analysis is then performed to reduce the data dimensions and the factors generated are used to investigate the interaction between Feng Shui woodlands and their surrounding landuses.

Correlation analysis and clustering analysis are adopted to investigate whether there are any relationship and association between Feng Shui woodlands and their neighbourhood. A GIS database is also constructed to store, manage and display this information.

6.2 The Landscape Ecological Value of Feng Shui Woodlands

There are 53 Feng Shui woodlands identified in this study. The woodlands are scattered throughout the study site and are concentrated in the Northeastern part of the study site. From calculated landscape metrics, within the study area, Feng Shui woodlands are found to be small in size, with an average patch size of 1.9 hectares, and their shape is close to small deciduous forests, with a mean fractal dimension of 1.23. Small woodland patches probably have lower ecological importance since they may contain less species inside and are susceptible to anthropogenic disturbance.

The Feng Shui woodlands' neighbourhood is, on average, nearly co-dominated by built-up area and vegetation covers, with small percentages of village and Feng Shui woodlands as well as negligible amount of water body nearby. Woodlands in built-up area dominated landscape are supposed to suffer greater anthropogenic harms while vegetation covers are supposed to be capable of buffering these harms.

Two and three factors are extracted by factor analysis for calculated landscape metrics and estimated landuse composition respectively. For calculated landscape metrics, two factors related to size and shape of woodland patches are extracted, with the highest loadings in radius of gyration and fractal dimension respectively. For estimated landuse composition, various kinds of landuse compositions show a high correlation within 100 meter, 300 meter and 500 meter, which means that the landuse composition is predictable throughout a buffer of 500 meter. Three factors representing 1) the ratio of percentage of built-up area to that of vegetation cover, 2) percentage of village, 3) percentage of Feng shui woodlands nearby.

Correlation is performed to investigate possible relationship and association between patch physical characteristics and landuse composition. No significant correlation is found between any pairs of patch physical characteristics factors and landuse factors. This means that landuse impact on Feng Shui woodlands can be considered to be minimal and physical characteristics of Feng Shui woodlands are insensitive to their surrounding landuse, which can be attributable to preservation by villagers and designation of woodlands into green belt zones. Clustering analysis provides a classification of Feng Shui woodlands based on their patch characteristics and surrounding landuse composition. From clustering analysis, three homogeneous clusters are formed for ease of interpretation of the landscape ecology of Feng Shui woodlands. Cluster 1 woodlands are small, complex and isolated, embedded in a landscape co-dominated by built-up area and vegetation. Though their shape is complex, these small size woodlands may contain less species and thus of less ecological value. Woodlands of this group are more vulnerable to urban development due to their small size.

Cluster 2 is composed of woodlands of moderate size and simple shape, surrounded by a largely vegetated landscape. Characteristic of simple shape of these woodlands is evidence that they have been suffering from human disturbance. They are associated with small villages or even no village behind such as Woods 1 and Woods 2, and are closely located with other Feng Shui woodlands. Viewing from landscape level, the landscape of these woodlands would have a high landscape ecological value since they are embedded in a green landscape and surrounded by a large portion of Feng Shui woodlands, which is an attraction to green tours.

For Cluster 3, the composing woodlands are lying behind village of medium size and embedded by a built-up area dominated landscape. Woodlands of Cluster 3 are most natural among three clusters as they are complex in shape and of large size, which mean the woodlands have been minimally affected by human activity and of higher ecological importance. However, at landscape level, the landscape ecological value of the landscape of these woodlands would not be so high due to a large portion of built-up area surrounded.

6.3 Limitations of This Study

The Feng Shui woodlands inventory constructed in this study is constrained by the spatial coverage of satellite imagery used. From Webb's study (1996), 88 Feng Shui woodlands were found in the north district and only 26 were found falling in my study site. Most of them are near Sha Tau Kok, Luk Keng, Pat Sin Leng and Plover Cove country parks, where is the most northeastern region of New Territories. It is the intrinsic problem of using remotely sensed technique to study environment. It can only be tackled with collecting more satellite imageries covering the whole territory so as to construct a Feng Shui woodlands database for the whole territory.

Besides, in the temporal scale, this study only investigates spatial distribution of Feng Shui woodlands at one temporal instant. It provides no means for temporal comparison of Feng Shui woodlands, which would be important for detecting any change caused by change of surrounding landuses. Regularly comparing patch metrics of Feng Shui woodlands and landuse composition near them can help ascertain the landscape ecological quality of Feng Shui woodlands over time.

Another limitation in this study can be attributable to the raster nature of remotely sensed data. It would alter accuracy of extraction of physical variables such as area and perimeter, of the woodland patches. It also makes delineation of patch boundary difficult. This intrinsic problem was solved by obtaining the finest spatial resolution imagery, IKONOS with 4-meter spatial resolution, available at the start of this study, and such a fine spatial resolution imagery provides a good visual detail for delineation of patch boundary.

Bibliography

Atauri, J.A., Bravo, M.A. and Ruiz, A., 2000, Visitor's Landscape Preferences as a Tool for Management of Recreational Use in Natural Areas: A Case Study in Sierra De Guadarrama (Madrid, Spain), *Landscape Research*, 25(1): 49-62.

Bastian, O., 2001, Landscape Ecology-Towards a Unified Discipline?, Landscape Ecology, 16(8):757-766.

Catt, P., 1986, Vegetation, *a Geography of Hong Kong*, 2nd edition (T. N. Chiu and C. L. So ed), Oxford University Press, 118-147.

Cheung, S.C.H., 1999, The Meanings of a Heritage Trail in Hong Kong, *Annals of Tourism Research*, 26(3):570-588.

Chu, W.H., 1998, *Conservation of terrestrial biodiversity in Hong Kong*, M.Phil. thesis, The University of Hong Kong.

Chu, W.H. and Xing, F., 1997, A Checklist of vascular plants found in fung shui woodlands in Hong Kong, *Memoirs of the Hong Kong Natural History Society*, 21: 151-172.

Crews-Meyer, K.A., 2002, Characterizing Landscape Dynamism Using Paneled-Pattern Metrics, *Photogrammetric Engineering and Remote Sensing*, 68(10):1031-1040.

Collinge, S.K., 1996, Ecological Consequences of Habitat Fragmentation: Implications for Landscape Architecture and Planning, *Landscape and Urban Planning*, 36(1):59-77.

Dudgeon, D. and Corlett, R., 1994, *Hills and Streams: An Ecology of Hong Kong*, Hong Kong University Press, 72-76.

Dunn, C.P., Sharpe, D.M., Guntenspergen, G.R., Stearns, F. and Yang, Z., 1991, Methods for Analyzing Temporal Changes in Landscape Pattern, *Quantitative Methods in Landscape Ecology* (Turner, M.G. and Gardner, R.H., ed), Springer-Verlag, New York.

Fan, W., 1992, Village Feng Shui Principle, *Chinese Landscape: The Village As Place* (Ronald G. Knapp ed.), Honolulu: University of Hawaii Press, 35-45.

Forman, R.T.T. and Gordon, M., 1986, *Landscape Ecology*, John Wiley & Sons, New York, 8-31, 175.

Forman, R.T.T., 1995, *Land Mosaics: The Ecology of Landscapes and Regions*, Cambridge University Press, Cambridge.

Franklin, S.E., Hall, R.J., Moskal, L.M., Maudie, A.J. and Lavigne, M.B., 2000, Incorporating Texture into Classification of Forest Species Composition from Airborne Multispectral Images, *International Journal of Remote Sensing*, 21(1):61-79.

Frohn, R.C., 1998, *Remote Sensing for Landscape Ecology: New Metric Indicators for Monitoring, Modeling, and Assessment of Ecosystems*, Lewis Publishers, Boca Raton.

Fuller, D.O., 2001, Forest Fragmentation in Loudoun County, Virginia, USA evaluated with multitemporal Landscape Imagery, *Landscape Ecology*, 16(7):627-642.

Gardner, R.H., O'Neill, R.V. and Turner, M.G., 1993, Ecological Implications of Landscape Fragmentation, *Humans as Components of Ecosystems* (McDonnell, M.J. and Pickett, S.T.A. ed.), Springer-Verlag, New York, 208-226.

Griffiths, G.H., Lee, J. and Eversham, B.C., 2000, Landscape Pattern and Species Richness; Regional Scale Analysis from Remote Sensing, *International Journal of Remote Sensing*, 21(13&14):2685-2704.

Griffiths, G.H. and Mather, P.M., 2000, Editorial—Remote Sensing and Landscape Ecology: Landscape Patterns and Landscape Change, *International Journal of Remote Sensing*, 21(13&14):2537-2539.

Haines-Young, R. and Chopping, M., Quantifying Landscape Structure: A Review of Landscape Indices and Their Application of Forested Landscapes, *Progress in Physical Geography*, 20(4):418-445.

Hammond, J., 1992, Xiqi Village, Guangdong, *Chinese Landscape: The Village As Place* (Ronald G. Knapp ed.), Honolulu: University of Hawaii Press, 98-99.

Hase, P.H. and Yip, L.M., 1992, Sheung Wo Hang Village, Hong Kong, *Chinese Landscape: The Village As Place* (Ronald G. Knapp ed.), Honolulu: University of Hawaii Press, 79-94.

Huang, S.M., 1992, Lincun Village, Fujian, *Chinese Landscape: The Village As Place* (Ronald G. Knapp ed.), Honolulu: University of Hawaii Press, 228-232.

Jensen, R.J., 2000, *Remote Sensing of the Environment: an Earth Resource Perspective*, Prentice Hall, New Jersey, 333-378.

Kelly, M. and Meentemeyer, R.K., 2002, Landscape Dynamics of the Spread of Sudden Oak Death, *Photogrammetric Engineering and Remote Sensing*, 68(10):1001-1009.

Krummel, J.R., Gardner, R.H., Sugihara, G., O'Neill, R.V. and Coleman, P.R., 1987, Landscape Patterns in a disturbed Environment, *Oikos,* 48:321-324.

LaGro, J., Jr., 1991, Assessing patch shape in landscape mosaics, *Photogrammetric Engineering & Remote Sensing*, 57:285-93.

Landsat 7 Science Data Users Handbook web page, visit in July 2003. Available at the following website:
http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_site_map.html

Leitão, A.B. and Ahern, J., 2002, Applying Landscape Ecological Concepts and Metrics in Sustainable Landscape Planning, *Landscape and Urban Planning*, 59(2):65-93).

Liu, A.J. and Cameron, G.N., 2001, Analysis of Landscape Patterns in Coastal Wetlands of Galveston Bay, Texas (USA), *Landscape Ecology*, 16(7):581-595.

Liu, B.Z., 1992, Dangjia Village, Shaanxi, *Chinese Landscape: The Village As Place* (Ronald G. Knapp ed.), Honolulu: University of Hawaii Press, 132.

Liu, Laurence G., 1989, *Chinese Architecture*, Academy Editions, London, 29, 34, 148-149, 156, 172, 219, 222, 274.

Luque, S.S., 2000, The Challenge to Manage the Biological Integrity of Nature Reserves: a Landscape Ecology Perspective, *International Journal of Remote Sensing*, 21(13&14):2613-2643.

Mandelbrot, B.B., 1977, *Fractals, Form, Chance, and Dimension*, Freeman, San Francisco.

MacArthur, R.H. and Wilson, E.O., 1963, An Equilibrium Theory of Insular Zoogeography, *Evolution*, 17:373-387.

McComb, W.C., 1999, Forest Fragmentation: Wildlife and Management Implicatons Synthesis of the Conference, *Forest Fragmentation: Wildlife and Management Implications* (Rochelle, T.A., Lehmann, L.A. and Wisniewski, J., ed), Leiden, Boston, 295-301.

McGarigal, K., Cushman, S. A., Neel, M. C. and Ene, E., 2002, FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps, Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site:
www.umass.edu/landeco/research/fragstats/fragstats.html

Narasimha Rao, P.V., Sesha Sai, M.V.R., Sreenivas, K., Krishna Rao, M.V., Rao, B.R.M., Dwivedi, R.S. and Venkataratnam, L., 2002, Textural Analysis of IRS-1D Panchromatic Data for Land Cover Classification, *International Journal of Remote Sensing*, 23(17):3327-3345.

Naveh, Z. and Lieberman, A.S., 1983, *Landscape Ecology—Theory and Application*, Springer-Verlag, New York.

Ney-Nifle, M. and Mangel, M., 2000, Habitat Loss and Species-Area Relationship, *Conservation Biology*, 14(3):893-898.

O'Neill, R.V., DeAngelis, D.L., Waide, J.B. and Allen, T.F.H., 1986, *A Hierarchical Concept of Ecosystems*, Princeton University Press, New Jersey.

O'Neill, R.V., Hunsaker, C.T., Timmins, S.P., Jackson, B.L., Jones, K.B., Riitters, K.H. and Wickham, J.D., 1996, Scale Problems in Reporting Landscape Pattern at the Regional Level, *Landscape Ecology*, 11:169-180.

O'Neill, R.V., Hunsaker, C.T., Jones, K.B., Ritters, K.H., Wickham, J.D., Schwarz, P., Goodman, I.A., Jackson, B. and Baillargeon, W.S., 1997, Monitoring Environmental Quality at the Landscape Scale, *Bioscience*, 47(8):513-519.

O'Neill, R.V., Krummel, J.R., Gardner, R.H., Sugihara, G., Jackson, B., DeAngelis, D.L., Milne, B.T., Turner, M.G., Zygmunt, B., Christensen, S.W., Dale, V.H. and Graham, R.L., 1988, Indices of Landscape Pattern, *Landscape Ecology*, 1(3):153-162.

Pachepsky, Y.A. and Ritchie. J.C., 1998, Seasonal Changes in Fractal Landscape Surface Roughness Estimated From Airborne Laser Altimetry Data, *International Journal of Remote Sensing*, 19(13):2509-2516.

Planning Department, 2002, Working Paper No, 17—Major Development Constraints and Opportunities, Hong Kong 2030 Planning Vision and Strategy.

Planning Department and Environmental Resources Management, 2000, Sustainable Development for the 21st Century Final Report, 34-36, 45-46, 60-61.

Planning Department and Territory Development Department, 2003a, Development Proposals for Kwu Tung North/ Fanling North and Ping Che/ Ta Kwu Ling—Consultation Digest, Planning and Development Study on North East New Territories. Available at the following website: http://www.info.gov.hk/planning/p_study/prog_s/nwnent/nent_dp_digest_2nd/nent_con_digest_e.htm

Planning Department and Territory Development Department, 2003b, Development Proposals for Hung Shui Kiu—Consultation Digest, Planning and Development Study on North West New Territories. Available at the following website:
http://www.info.gov.hk/planning/p_study/prog_s/nwnent/nwnt_dp_digest_2nd/nwnt_con_digest.htm

Planning, Environment and Lands Branch, 1996, *A Consultative Digest Territorial Development Strategy Review '96*, Hong Kong, The Government Printer.

Risser, P.G., Karr, J.R. and Forman, R.T.T., 1984, *Landscape Ecology: Directions and Approaches*, Special Publication Number 2, Illinois Natural History Survey, Champaign, Illinois.

Riitters, K.H., O'Neill, R.V., Hunsaker, C.T., Wickham, J.D., Yankee, D.H., Timmins, S.P., Jones, K.B. and Jackson, B.L., 1995, A Factor Analysis of Landscape Pattern and Structure Metrics, *Landscape Ecology*, 10:23-39.

Ruzicka, M., Ruzickova, H. and Zigrai, F., 1978, Krajinne Zlozky, Pruvky a Struktura V Biologickon Planovani Krajinpy, *Quaestiones Geobiologicae*, 23:7-63.

Saura, S. and Martinez-Millan, J., 2000, Landscape Patterns Simulation with a Modified Random Clusters Method, *Landscape Ecology*, 15:661-678.

Saura, S. and Martinez-Millan, J., 2001, Sensitivity of Landscape Pattern Metrics to Map Spatial Extent, *Photogrammetric Engineering and Remote Sensing*, 67(9):1027-1036.

Schumaker, N.H., 1996, Using Landscape Indices to Predict Habitat Connectivity, *Ecology*, 77(4):1210-1225.

Sharma, S., 1996, *Applied Multivariate Techniques*, John Wiley, New York, 90-143, 185-236.

Space Imaging web page, visit in July 2003. Available at the following website:
http://www.spaceimaging.com/products/ikonos/spectral.htm

Sugihara, G. and May, R.M., 1990, Applications of Fractals in Ecology, *Tree*, 5(3):79-86.

Taylor, J.C., Brewer, T.R. and Bird, A.C., 2000, Monitoring Landscape Change in the National Parks of England and Wales using Aerial Photo Interpretation and GIS, *International Journal of Remote Sensing*, 21(13&14): 2737-2752.

Thrower, S.L., 1975, Floristics of the fung shui woodlands, *The Vegetation of Hong Kong: Its structure and change* (L. B. Thrower, ed.), Hong Kong: Royal Asiatic Society, Hong Kong Branch, 57-63.

Tinker, D.B., Resor, C.A.C., Beauvais, G.P., Kipfmueller, K.F., Fernandes, C.I. and Baker, W.L., 1998, Watershed Analysis of Forest Fragmentation by Clearcuts and Roads in a Wyoming Forest, *Landscape Ecology*, 13(3):149-165.

Toutin, T. and Cheng, P., 2000, Demystification of IKONOS, Earth Observation Magazine, 17-21.

Troll, C., 1971, Landscape Ecology (Geoecology) and Biogeocenology—A Terminological Study (translated by Yates, E.M.), *Geoforum* 8:43-46.

Turner, M.G., 1989, Landscape Ecology: The Effect of Pattern on Process, *Annual Review of Ecology and Systematics*, 20:171-197.

Turner, M.G., 1990, Landscape Changes in Nine Rural Counties in Georgia, *Photogrammetric Engineering and Remote Sensing*, 56(3):379-386.

Turner, M.G., Gardner, R.H. and O'Neill, R.V., 2001, *Landscape Ecology in Theory and Practice: Pattern and Process*, Springer-Verlag, New York.

Turner, M.G. and Ruscher, C.L., 1988, Changes in Landscape Patterns in Georgia, USA, *Landscape Ecology*, 1(4):241-251.

Urban, D.L., O'Neill, R.V. and Shugart, H.H., 1987, Landscape Ecology, *BioScience*, 37(2):119-127.

Walsh, S.J., Crews-Meyer, K.A., Crawford, T.W., Welsh, W.F., Entwisle, B. and rindfuss, R.R., 2001,Patterns of Change in Land Use, Land Cover, and Plant Biomass: Separating Intra- and Inter-annual Signals in Monsoon-Driven Northeast Thailand, *GIS and Remote Sensing Applications in Biogeography and Ecology* (Millington, A.C., Walsh, S.J. and Osborne, P.E. ed), Kluwer Academic Publishers, Boston, 91-108.

Webb, R., 1996, *The fung shui woodlands of Hong Kong: a study of culturally protected woodlands in the New Territories of Hong Kong*, Ph.D. thesis, The University of Wales.

Wickham, J.D. and Riitters, K.H., 1995, Sensitivity of Landscape Metrics to Pixel Size, *International Journal of Remote Sensing*, 16(18):3585-3594.

Website of Planning and Lands Bureau-1999 Press Releases, *香港未來城市規劃新藍圖*, visit in April 2002. Available at the following website: http://www.plb.gov.hk/chi/press_releases/convert.asp?file=1999/990105bc.htm

Website of Planning and Lands Bureau-2000 Press Releases, *Building Heritage integrated into town planning*, Visit in April 2002. Available at the following website: http://www.plb.gov.hk/eng/press_releases/convert.asp?file=2000/000304e.htm

Wickham, J.D., Riitters, K.H., O'Neill, R.V., Jones, K.B. and Wade, T.D., 1996, Landscape "Contagion" in Raster and Vector Environments, *International Journal of Geographical Information Systems*, 10(7):891-899.

Wiens, J.A., 2002, Central Concepts and Issues of Landscape Ecology, *Applying Landscape Ecology in Biological Conservation* (Gutzwiller, K.J., ed), Springer-Verlag, New York,

Young, C.H. and Jarvis, P.J., 2001, Measuring Urban Habitat Fragmentation: an example from the Black Country, UK, *Landscape Ecology*, 16(7):643-658.

Zhuang, X.Y. and Corlett, R.T., 1997, Forest and forest succession in Hong Kong, China, *Journal of Tropical Ecology*, 14:857-866.

Appendix 1—Results from Factor Analysis and Clustering Analysis

GIS Ref.	Feng Shui Woodland names	Size	Shape	%Built/%Veg	%Village	%FSW	Cluster ID	Distance
6	Chau Tau Tsuen	1.23926	0.07112	-0.35734	-0.09038	-0.08476	3	0.96753
50	Chau Tau Tsuen 2	-0.05033	-0.80973	-0.76896	0.92871	2.36633	2	2.2807
12	Cheung Lek	-0.60923	-0.35797	-1.71230	-0.58004	-1.10585	2	2.44859
19	Fanling Lau	0.77166	0.83676	2.04101	0.75091	-0.59279	3	2.01266
17	Fanling Wai	-1.28657	1.49513	1.37035	3.38722	0.24466	1	3.05829
34	Ha Shan Kai Wat	-0.59527	-0.24804	-1.68026	-0.66624	-0.42309	2	2.01085
11	Hang Tau	0.86504	-1.06568	-0.67462	1.72438	-0.72124	3	2.42192
10	Hang Tau Tai Po	0.09637	-1.34819	0.01885	3.00117	-0.39689	1	3.18954
3	Ho Sheung Heung	3.15209	1.64102	0.83903	0.36582	-0.79737	3	2.71471
53	Hung Kiu San Tsuen	0.81448	0.64440	0.96147	-0.75513	-1.27025	3	1.27367
28	Hung Leng	-1.97488	0.14725	1.34264	1.83596	-0.85567	1	2.01102
8	Kam Tsin	-0.81586	0.17185	-0.45270	1.13056	-1.00395	1	0.93437
25	Ko Po	0.84251	0.35266	1.06149	-0.11074	-0.06022	3	1.04639
45	Lei Uk	-1.65836	1.96592	-0.37617	-0.07929	0.42501	1	1.93521
13	Lin Tong Mei	-0.42725	0.52192	0.03891	-0.34451	-0.97798	3	1.3757
18	Ling Shan Tsuen	0.34505	0.14242	1.21720	0.14414	-0.37563	3	1.19281
1	Liu Pok	-1.47952	0.81397	-1.69073	0.04221	-0.93175	1	1.94466
23	Lo Wai	0.65503	-0.96148	-1.31992	1.71164	2.46106	2	3.14725

GIS Ref.	Feng Shui Woodland names	Size	Shape	%Built/%Veg	%Village	%FSW	Cluster ID	Distance
2	Ma Tso Lung San Tsuen	-0.05246	1.11651	-0.85946	-0.63420	-0.94595	3	1.71841
52	Ma Tso Lung Shun Yee San Tsuen	0.61441	0.66855	-1.32624	-0.29506	-1.07746	3	1.66209
21	Ma Wat Wai	1.15708	0.02075	0.07718	1.77317	0.59596	3	2.2042
14	Ng Uk Tsuen	0.82321	-0.00610	1.56815	-0.85174	-1.34081	3	1.81364
49	Ping Che	0.84516	0.52263	0.81565	-0.26764	1.06768	2	1.79284
31	Ping Che Kak Tin	0.52683	-0.49681	0.31147	-0.33270	-0.39272	3	1.07152
29	Ping Che New Village	-0.56493	-1.55920	0.91408	-0.00963	0.53566	2	1.54564
15	Ping Kong	-0.66223	-0.47877	-0.85338	0.22433	-1.02855	1	1.74607
5	Pun Uk Tsuen	0.72721	-0.66434	-0.82964	-0.00480	0.44995	2	1.17409
26	San Tong Po	-0.58257	1.06932	-0.07491	-0.36489	1.12565	2	1.81224
48	Sheung Shan Kai Wat	-0.35855	-0.77553	-1.43107	-0.33546	0.65870	2	1.35072
35	Sheung Shan Kai Wat 2	0.08912	-0.07598	-1.13791	-0.46236	0.03996	2	1.31413
24	Siu Hang San Tsuen	2.70969	1.05835	-1.14196	-0.10161	-1.14516	3	2.44937
16	So Kwun Po	-0.58110	1.50049	2.03896	-0.36925	-0.86565	3	2.59502
36	Tai Po Tin	-1.73521	0.56211	-0.46494	-0.44203	-0.04549	1	1.61389
9	Tsung Pak Long	-0.33574	1.55907	0.32623	0.20388	-0.80934	1	1.41534
4	Tsung Yuen	-0.57324	2.92744	-0.37521	0.40773	-0.01607	1	2.38448
22	Tsz Tong Tsuen	1.15962	-0.48890	-1.57948	0.55638	0.69487	2	2.1544
20	Wo Hop Shek	0.90425	-0.14012	-0.44323	0.21796	-0.55580	3	0.88839

GIS Ref.	Feng Shui Woodland names	Size	Shape	%Built/%Veg	%Village	%FSW	Cluster ID	Distance
51	Wo Hop Shek 2	-0.20308	-0.97113	-0.11160	0.65687	0.48047	2	1.15408
27	Woods 1	0.50704	-0.62346	0.22980	-0.45528	-0.25582	2	1.14324
30	Woods 2	0.58987	-1.41850	0.91960	-0.76159	0.14722	2	1.60459
32	Woods 3	0.07635	-1.77176	0.11212	-0.98543	-1.05296	2	2.16277
33	Woods 4	0.55221	0.29802	-1.78531	-0.55552	-0.39536	3	2.11797
37	Woods 5	0.61331	0.01377	-0.05051	-1.06776	0.18560	2	1.23399
38	Woods 6	-0.27553	0.30664	0.36617	-0.95295	1.17112	2	1.28898
39	Woods 7	-0.44351	-1.47403	0.70458	-0.84544	2.28095	2	2.09435
40	Woods 8	-0.81132	0.22465	0.81137	-0.92717	2.17393	2	2.15731
41	Woods 9	-0.09923	0.17227	0.85003	-1.10520	1.21243	2	1.52791
42	Woods 10	-0.52442	-1.38406	1.11387	-1.34556	-0.56203	2	2.15981
43	Woods 11	-0.48894	-0.87974	-0.09546	-1.12117	-0.52033	2	1.45418
44	Woods 12	-0.17572	-0.64738	0.48148	-0.92664	1.08483	2	0.90356
46	Woods 13	-1.11701	-1.06564	0.26275	-0.56547	1.10004	2	1.28083
47	Woods 14	-0.50676	-1.31740	0.17290	-0.54995	1.07150	2	0.97903
7	Yin Kong	-1.68809	0.20490	0.62595	0.19979	-0.96664	1	1.33904

Appendix 2—Change of Percentage of Landuse for Feng Shui Woodlands across 500 meters

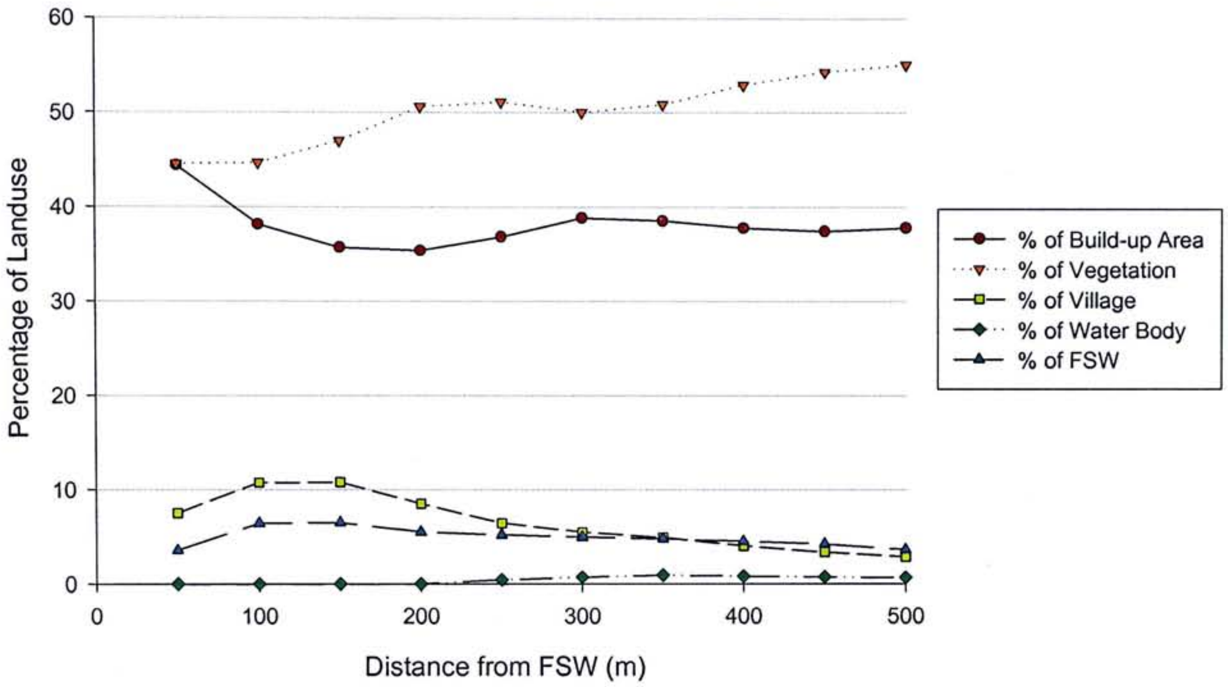


Figure A.1 Change of Percentage of Landuse in Chau Tau Tsuen FSW

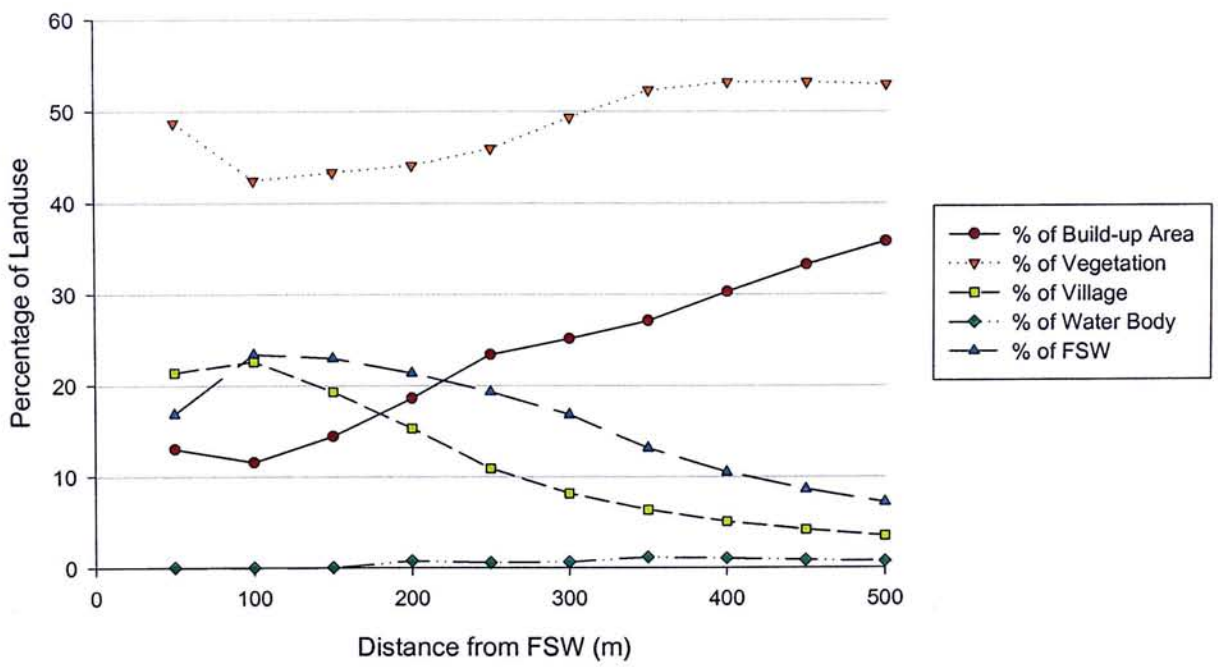


Figure A.2 Change of Percentage of Landuse in Chau Tau Tsuen 2 FSW

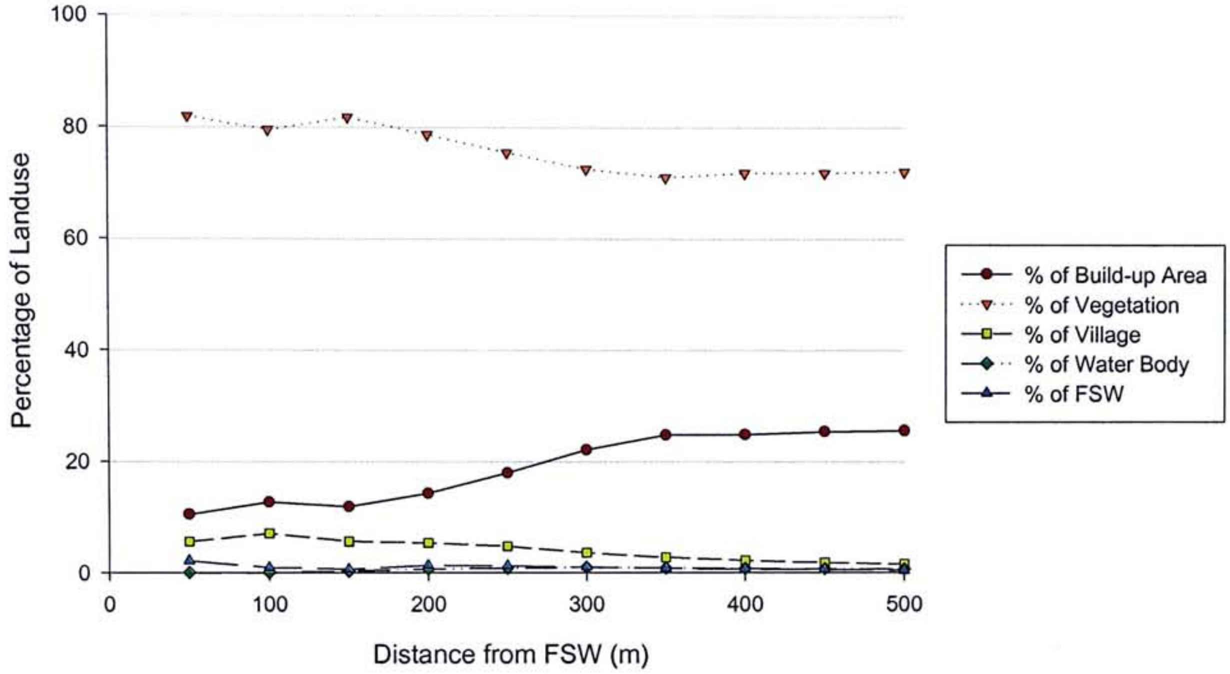


Figure A.3 Change of Percentage of Landuse in Cheung Lek FSW

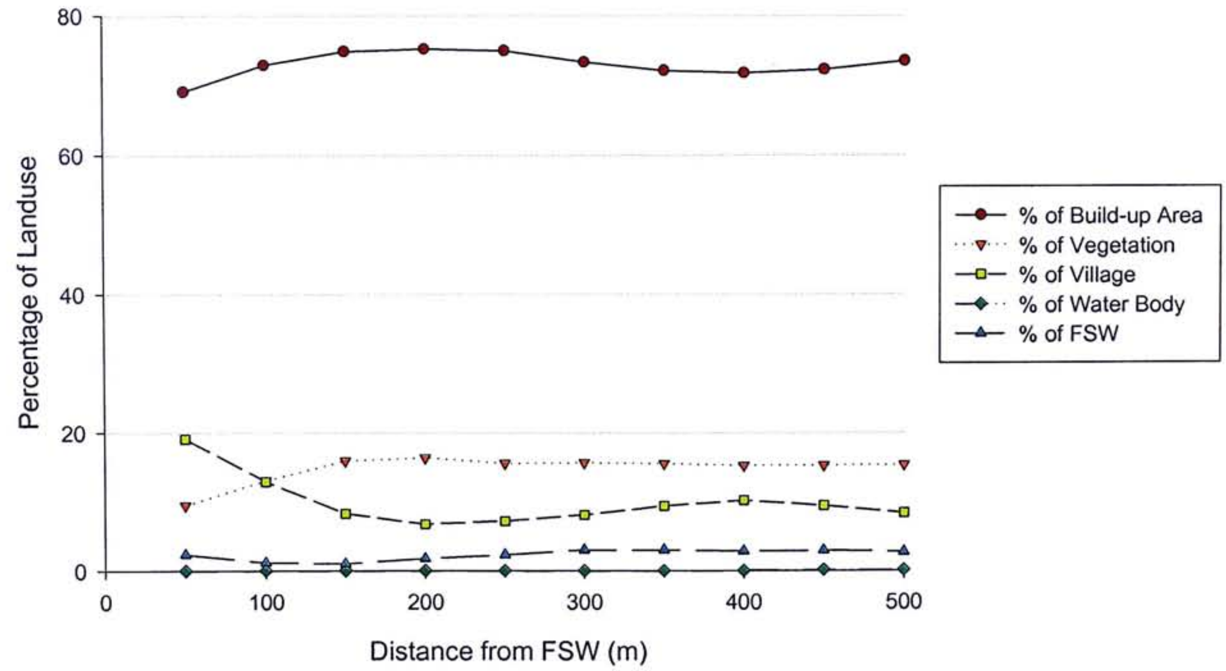


Figure A.4 Change of Percentage of Landuse in Fanling Lau FSW

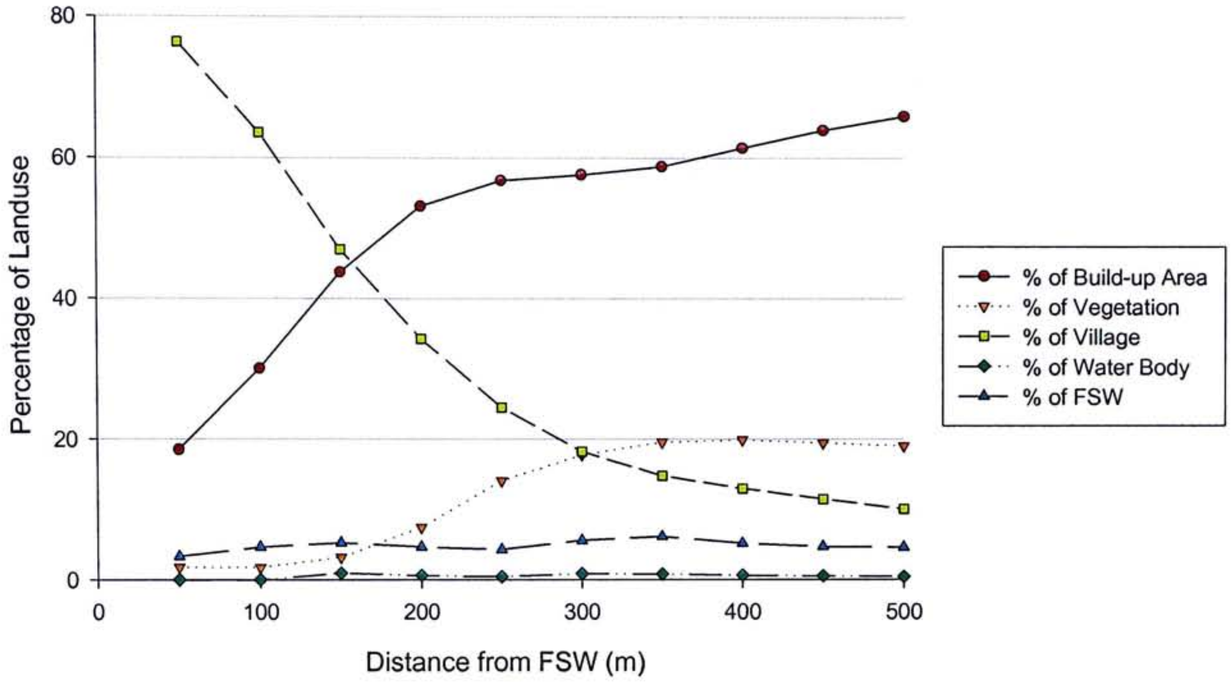


Figure A.5 Change of Percentage of Landuse in Fanling Wai FSW

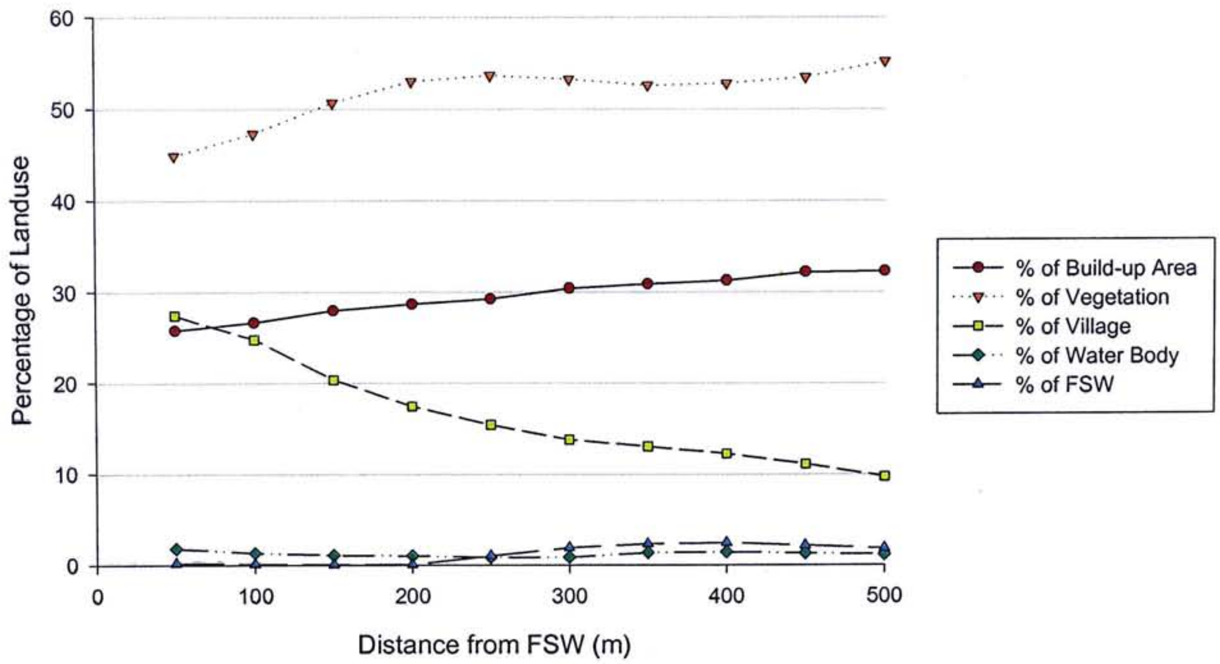


Figure A.6 Change of Percentage of Landuse in Hang Tau FSW

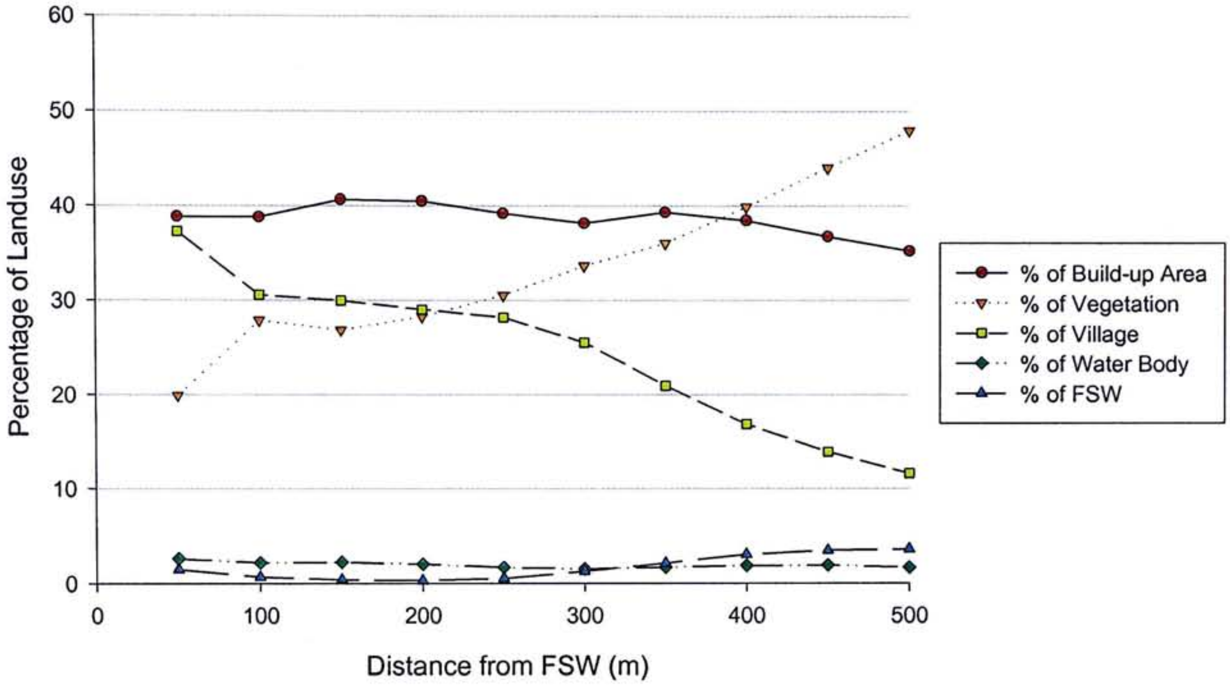


Figure A.7 Change of Percentage of Landuse in Hang Tau Tai Po FSW

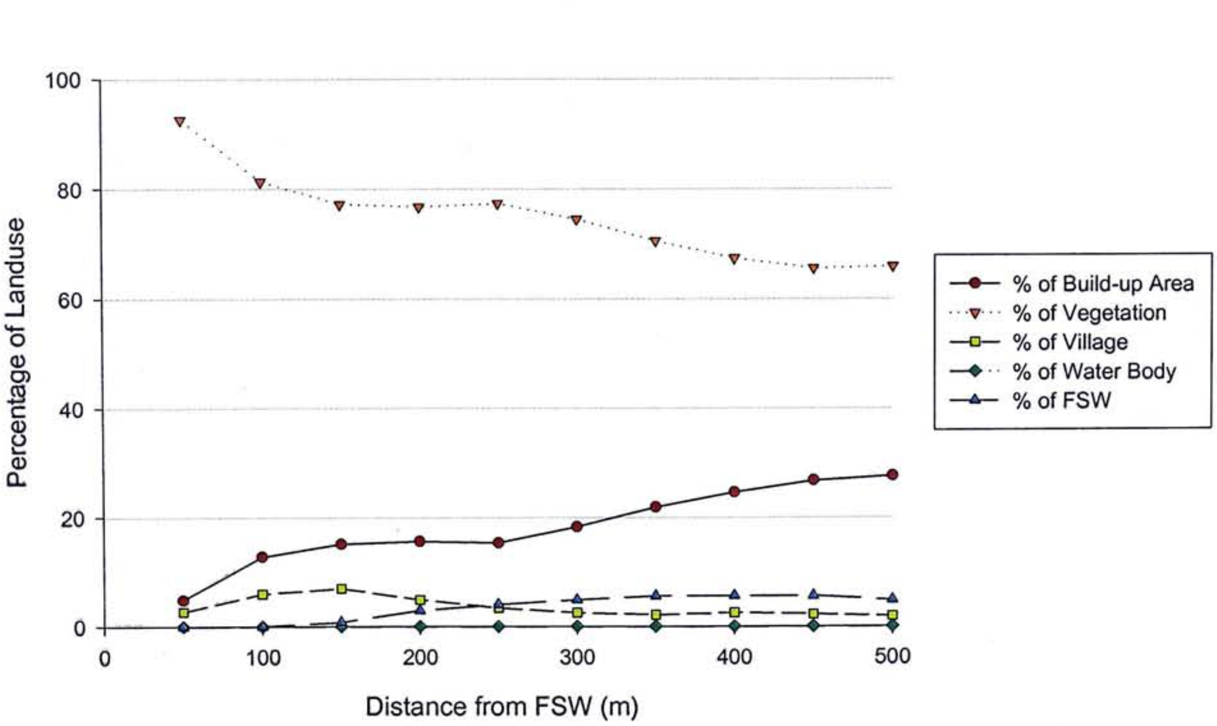


Figure A.8 Change of Percentage of Landuse in Ha Shan Kai Wat FSW

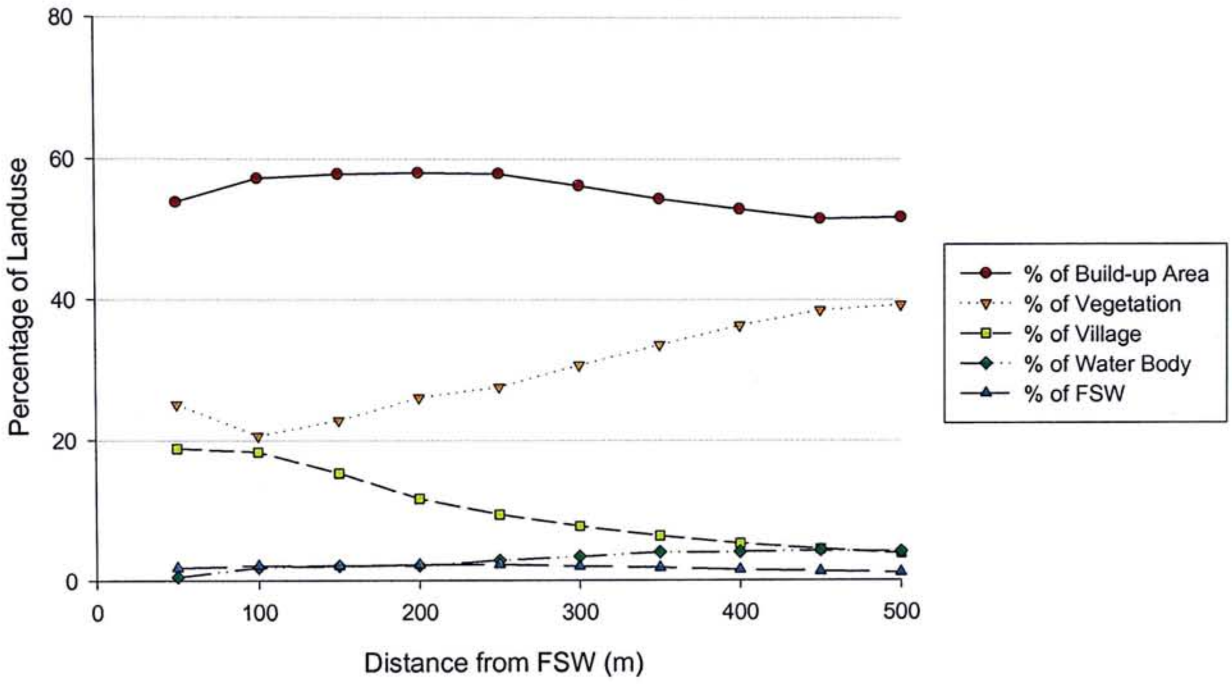


Figure A.9 Change of Percentage of Landuse in Ho Sheung Heung FSW

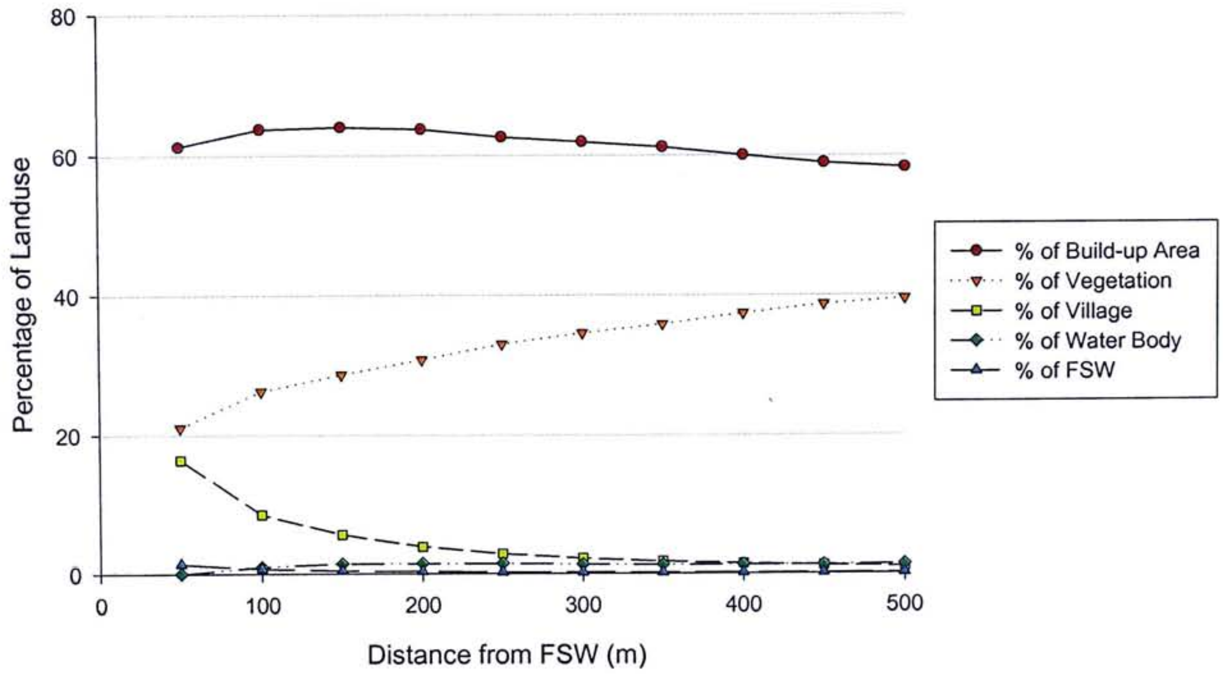


Figure A.10 Change of Percentage of Landuse in Hung Kiu San Tsuen FSW

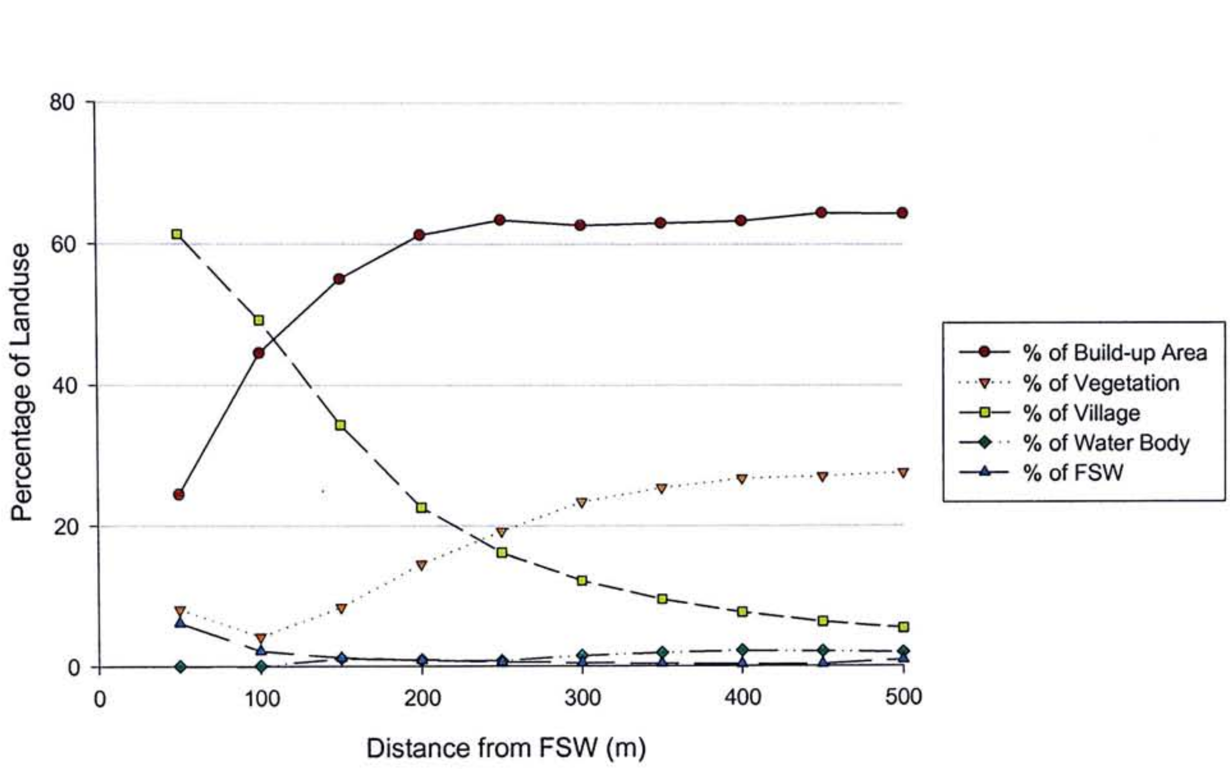


Figure A.11 Change of Percentage of Landuse in Hung Leng FSW

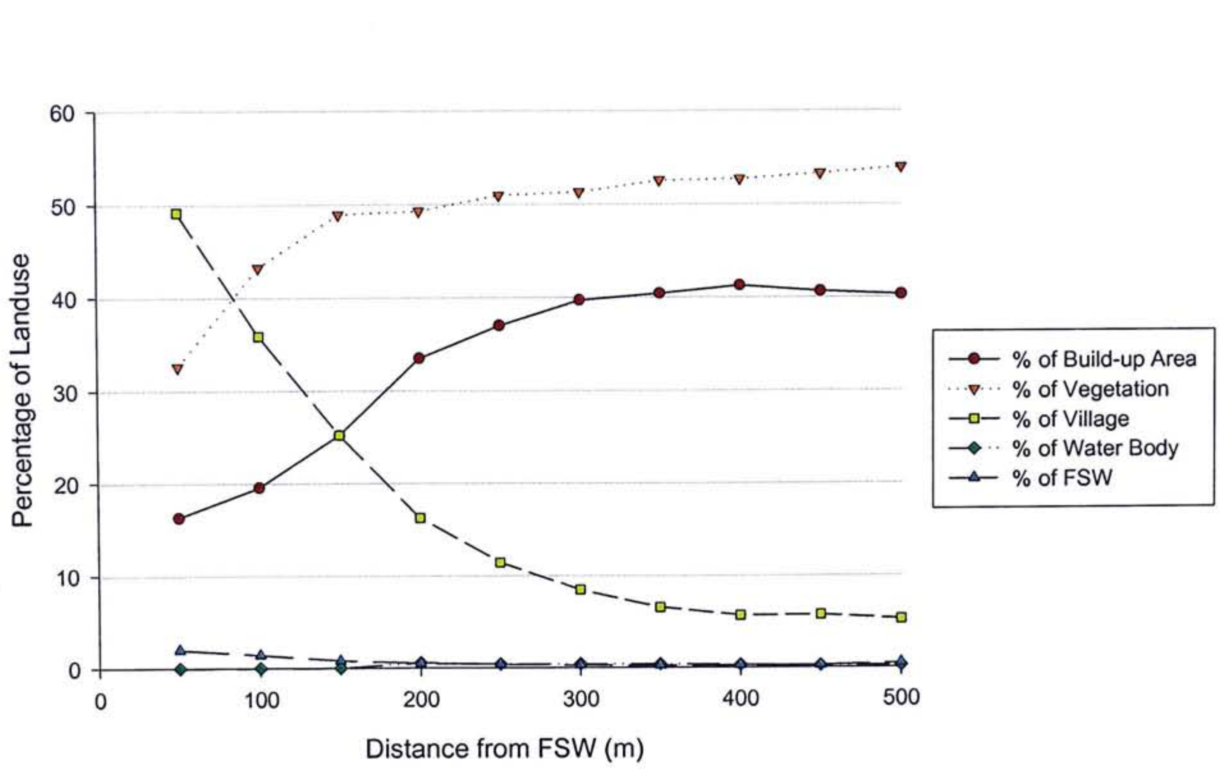


Figure A.12 Change of Percentage of Landuse in Kam Tsin FSW

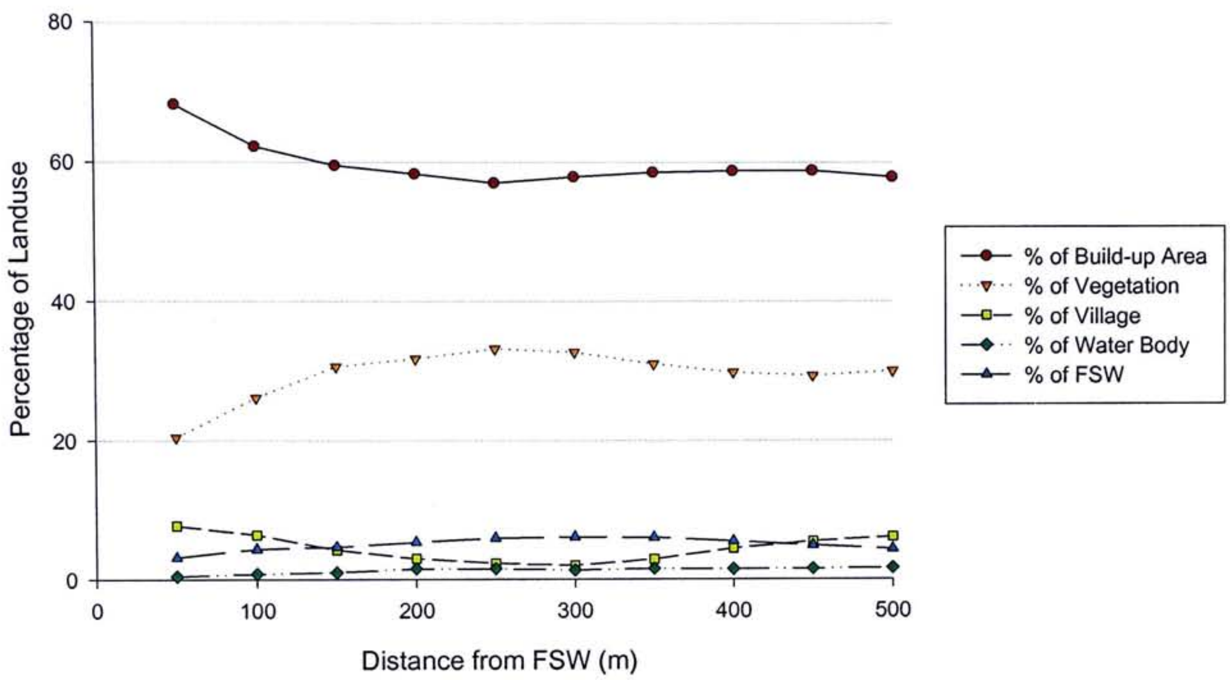


Figure A.13 Change of Percentage of Landuse in Ko Po FSW

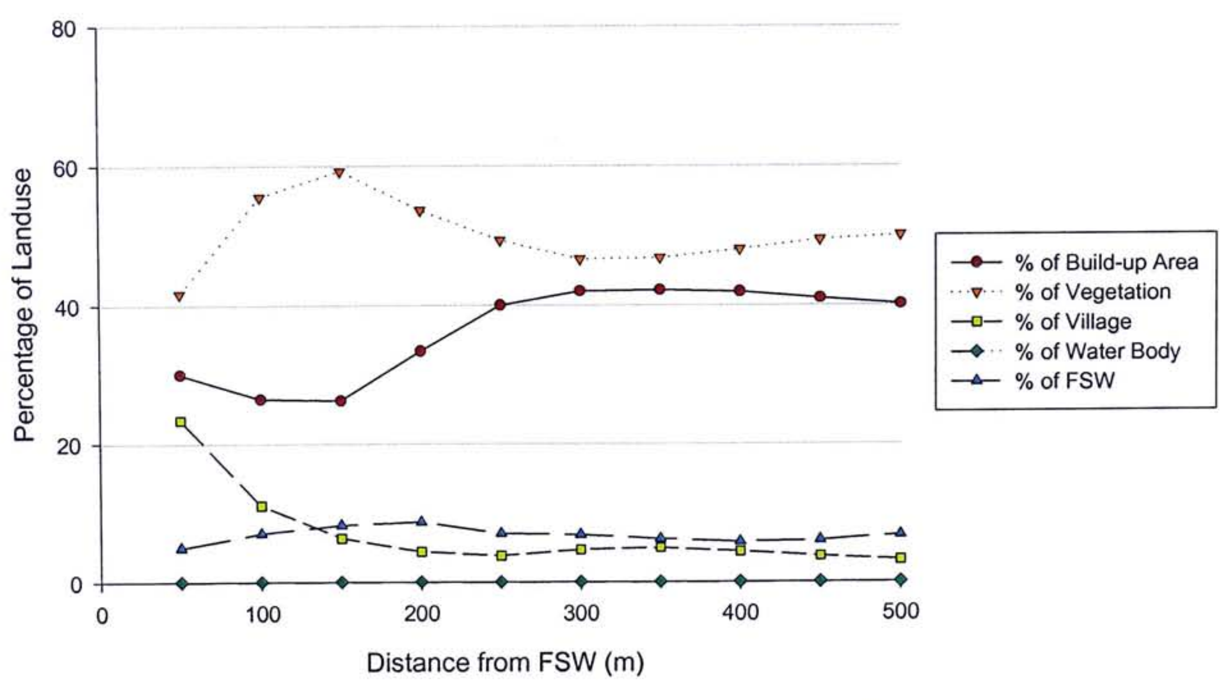


Figure A.14 Change of Percentage of Landuse in Lei Uk FSW

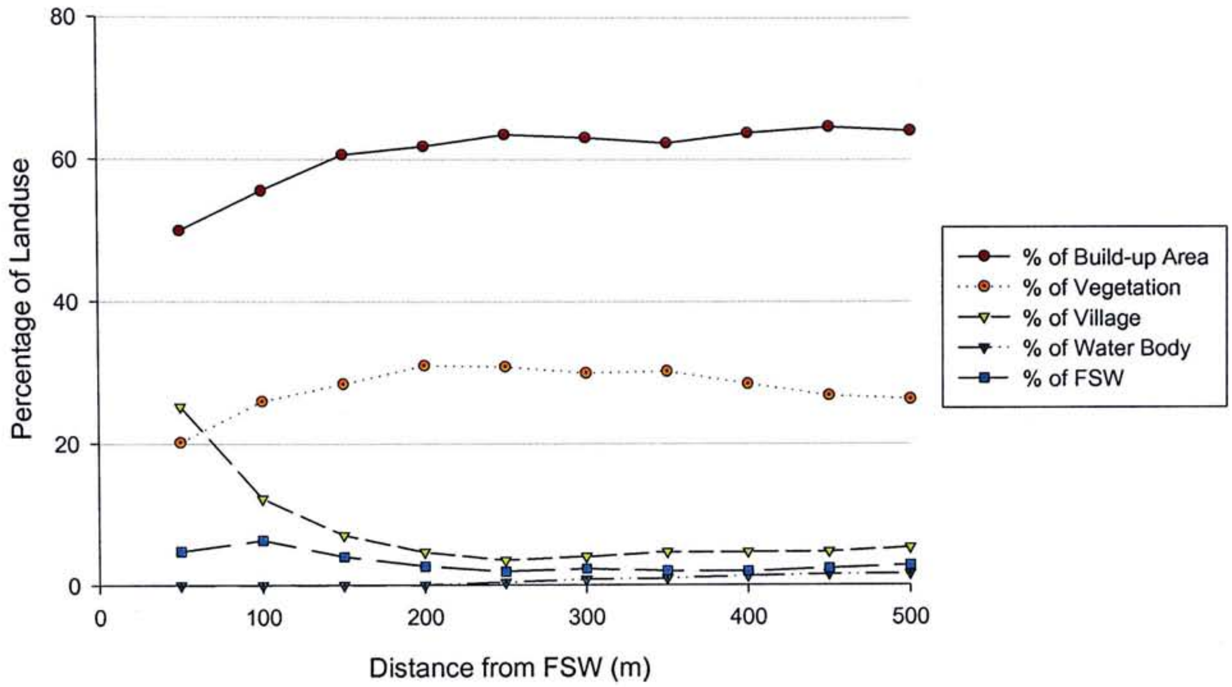


Figure A.15 Change of Percentage of Landuse in Ling Shan Tsuen FSW

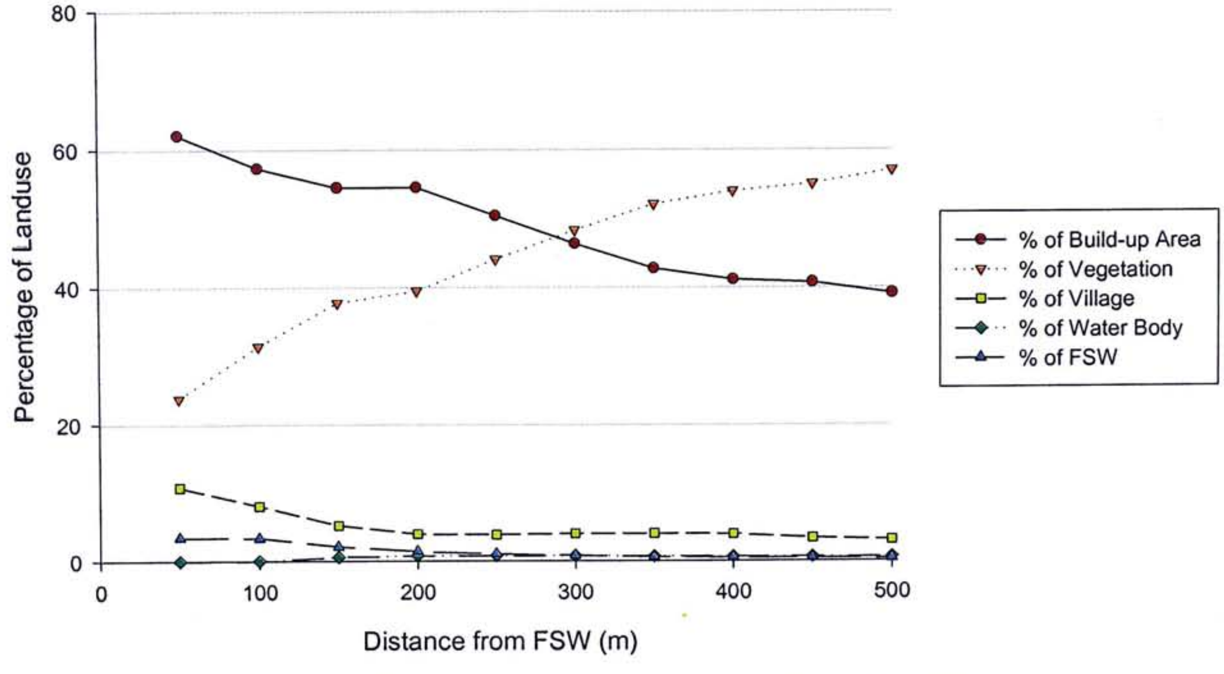


Figure A.16 Change of Percentage of Landuse in Lin Tong Mei FSW

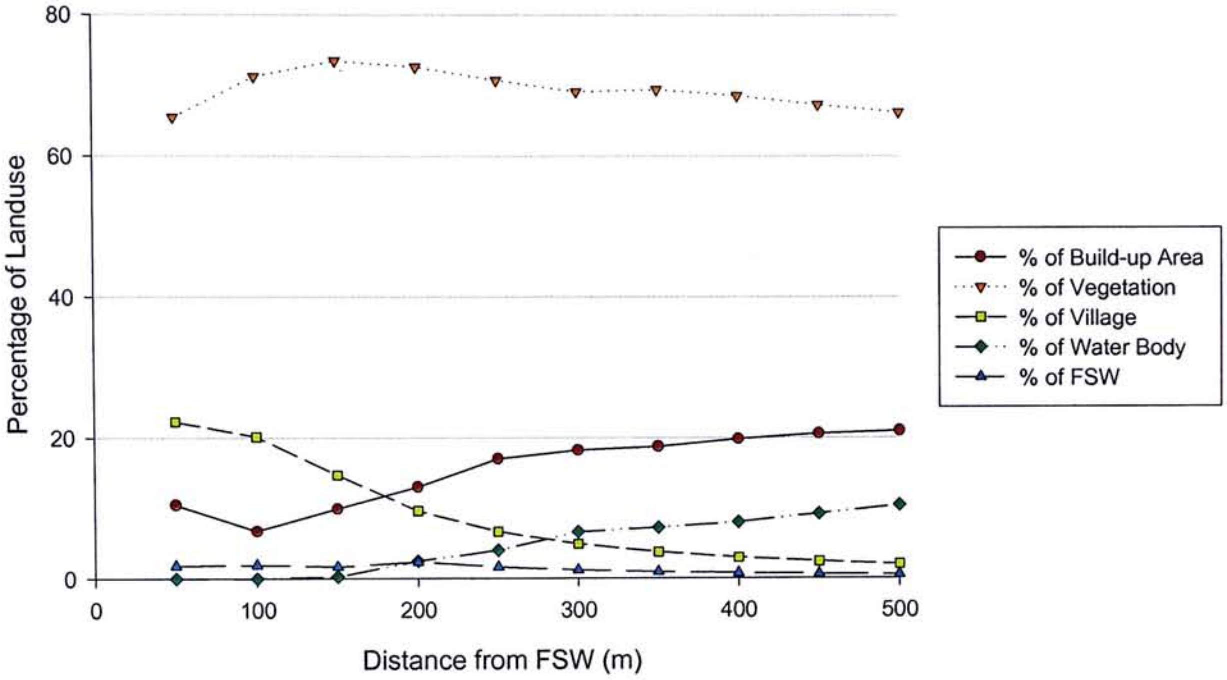


Figure A.17 Change of Percentage of Landuse in Liu Pok FSW

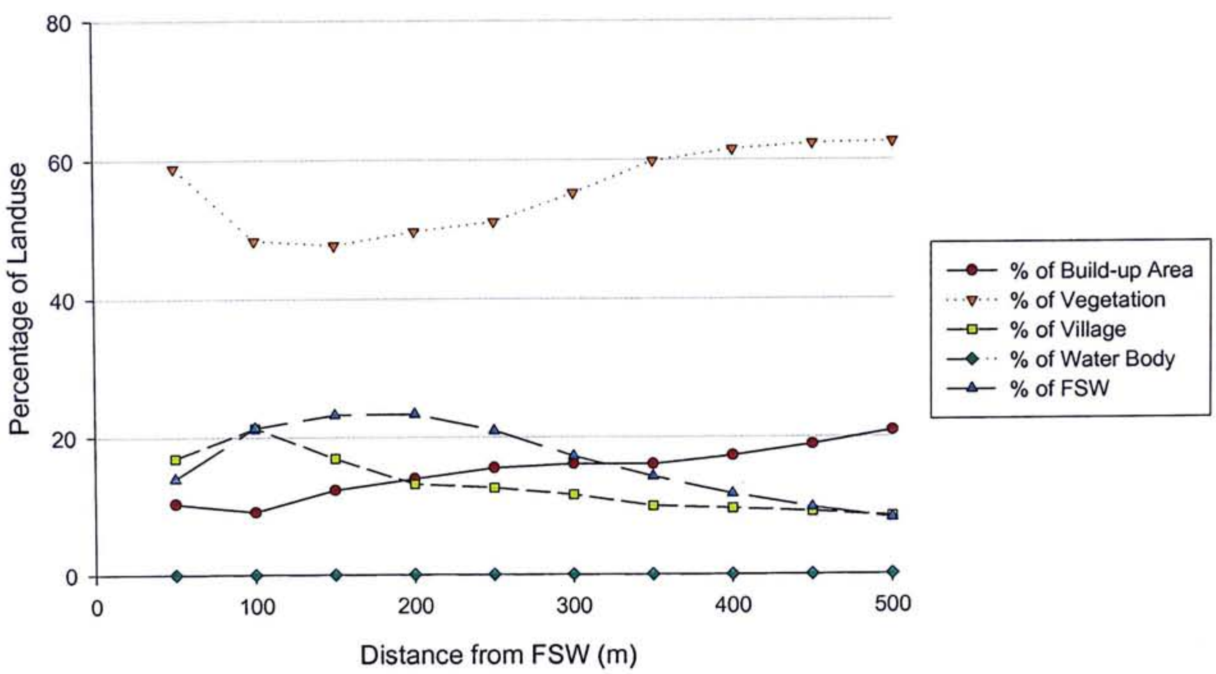


Figure A.18 Change of Percentage of Landuse in Lo Wai FSW

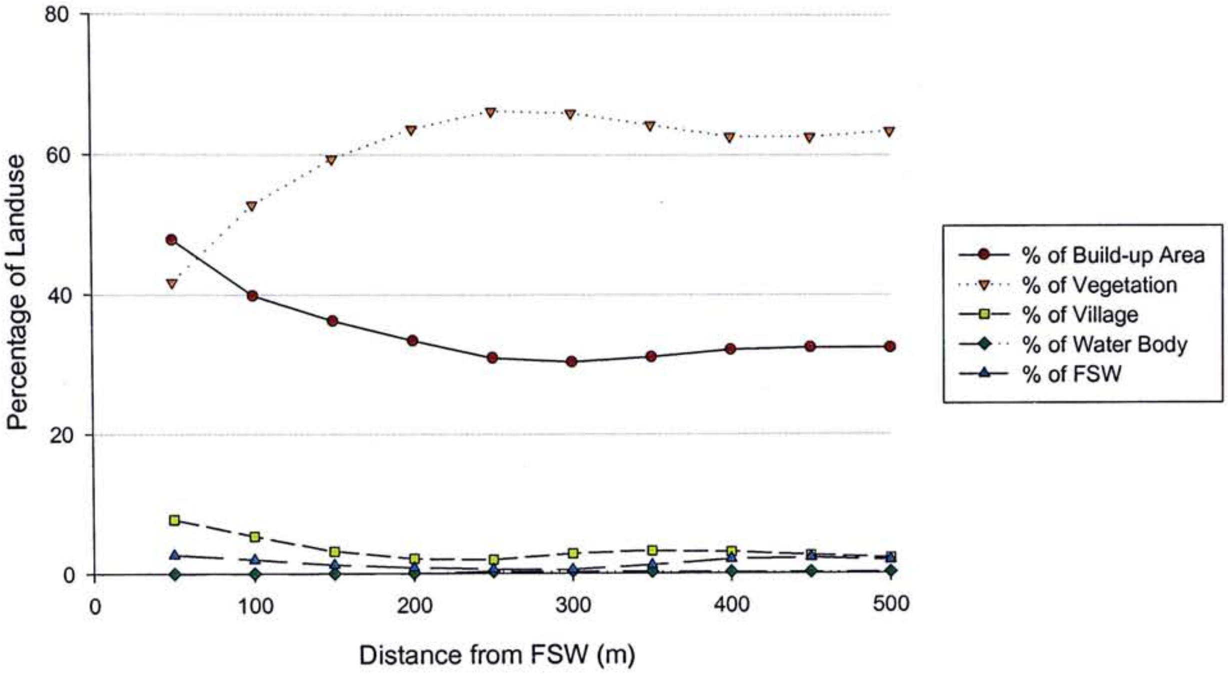


Figure A.19 Change of Percentage of Landuse in Ma Tso Lung San Tsuen FSW

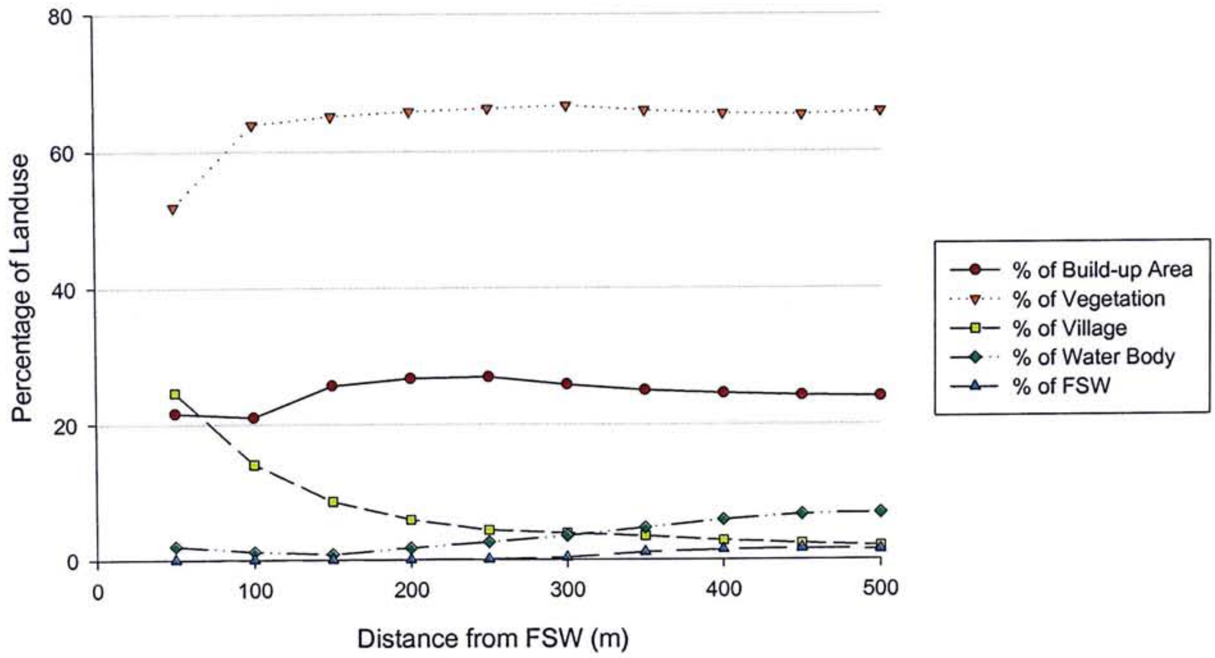


Figure A.20 Change of Percentage of Landuse in Ma Tso Lung Shun Yee San Tsuen FSW

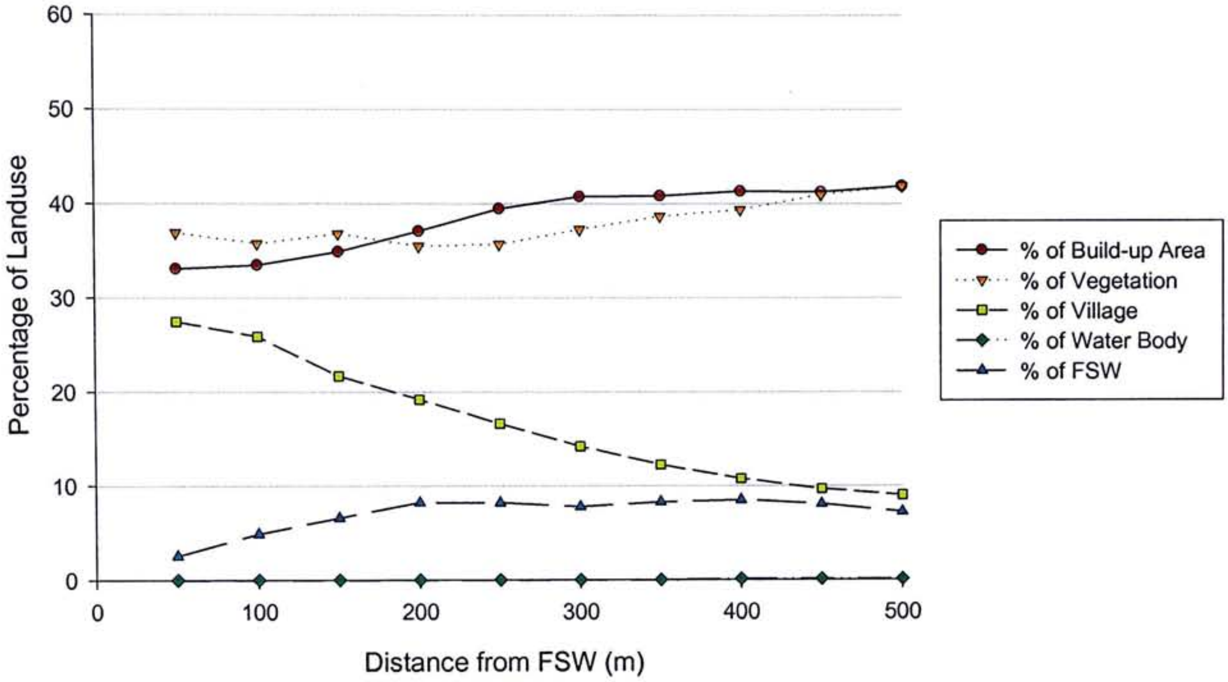


Figure A.21 Change of Percentage of Landuse in Ma Wat Wai FSW

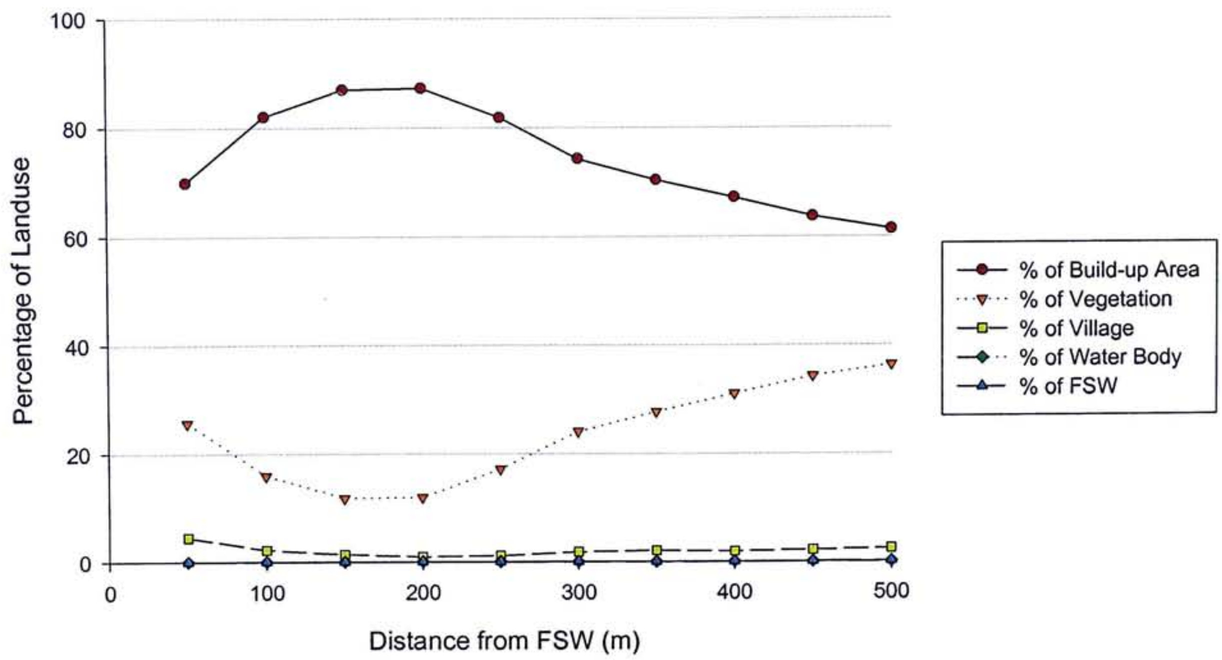


Figure A.22 Change of Percentage of Landuse in Ng Uk Tsuen FSW

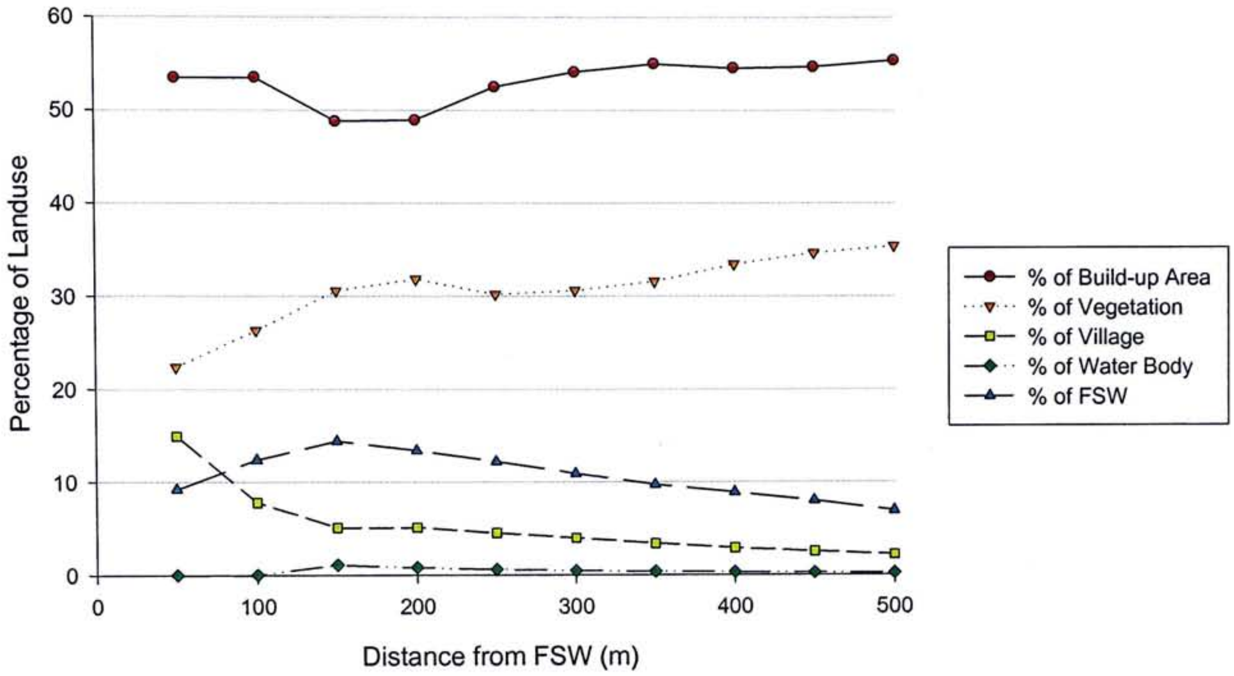


Figure A.23 Change of Percentage of Landuse in Ping Che FSW

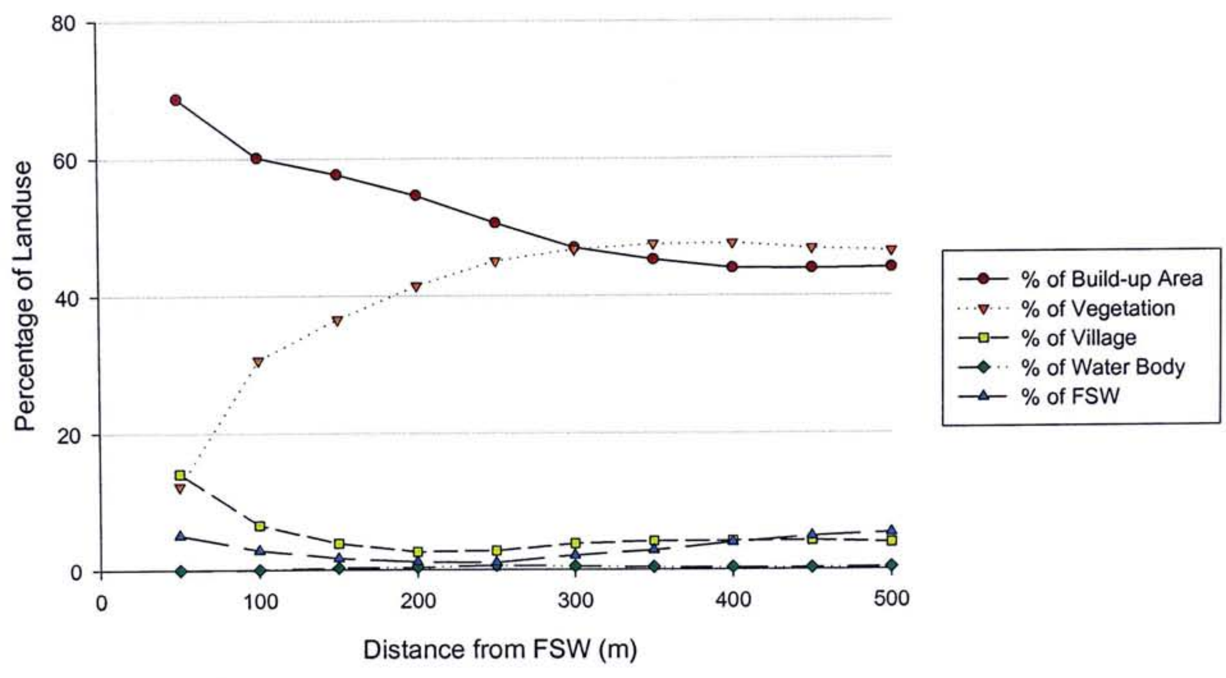


Figure A.24 Change of Percentage of Landuse in Ping Che Kak Tin FSW

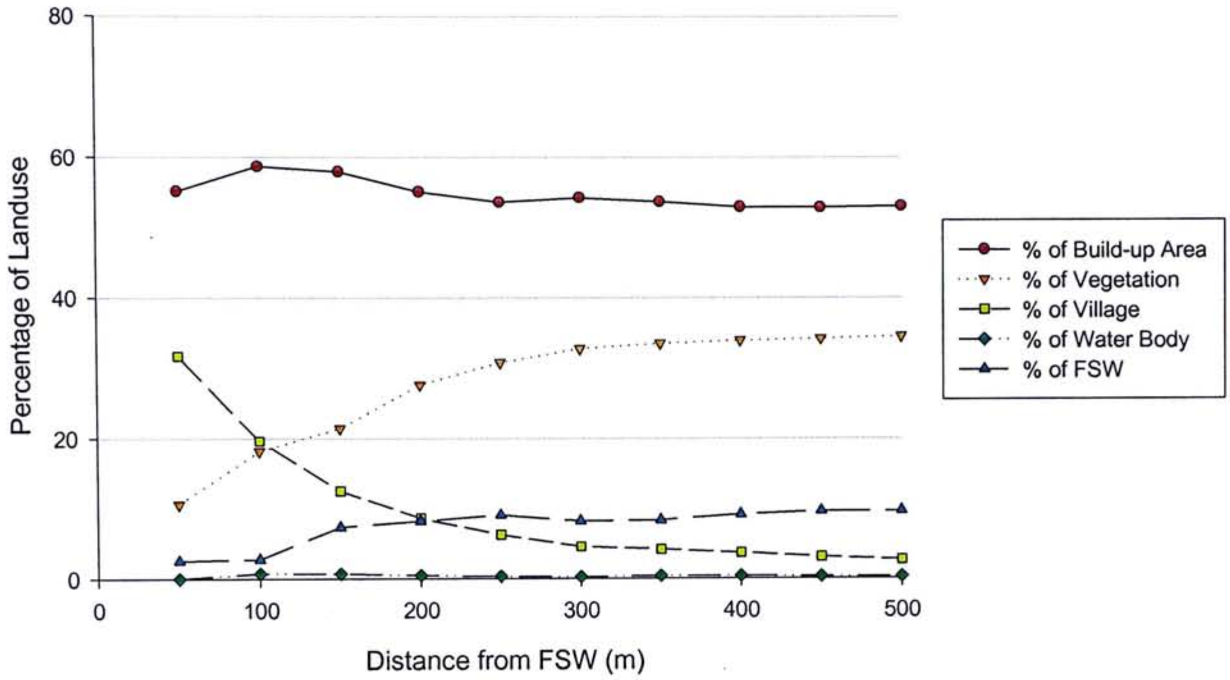


Figure A.25 Change of Percentage of Landuse in Ping Che New Village FSW

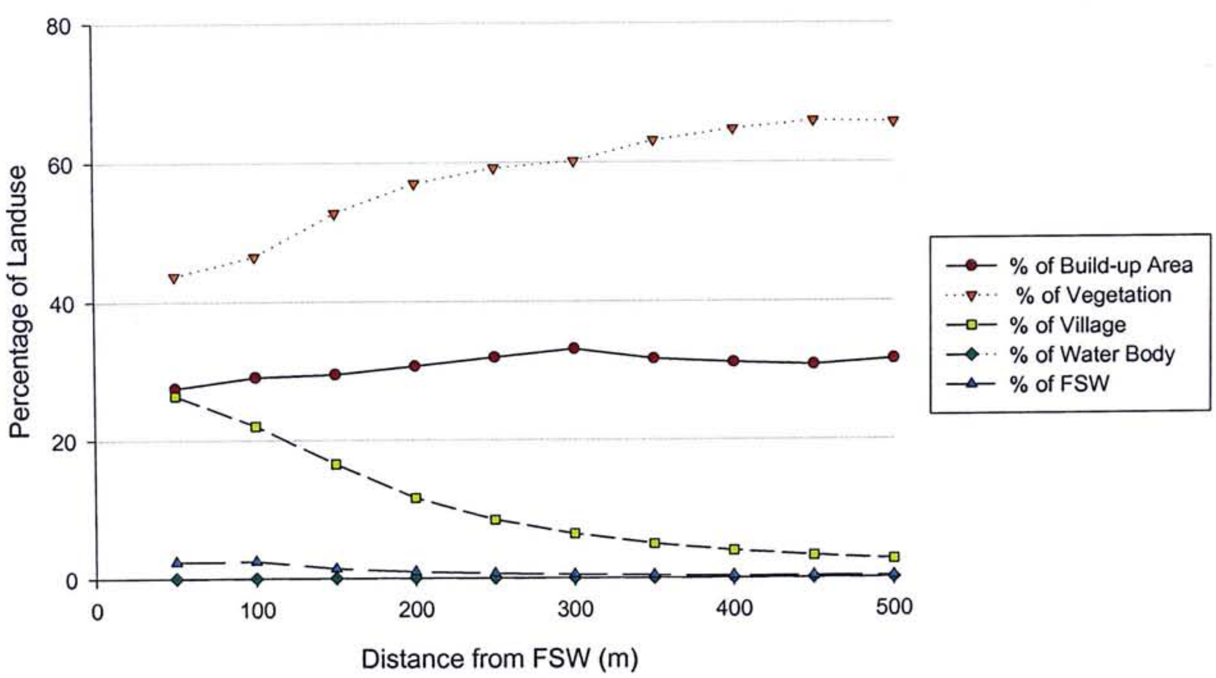


Figure A.26 Change of Percentage of Landuse in Ping Kong FSW

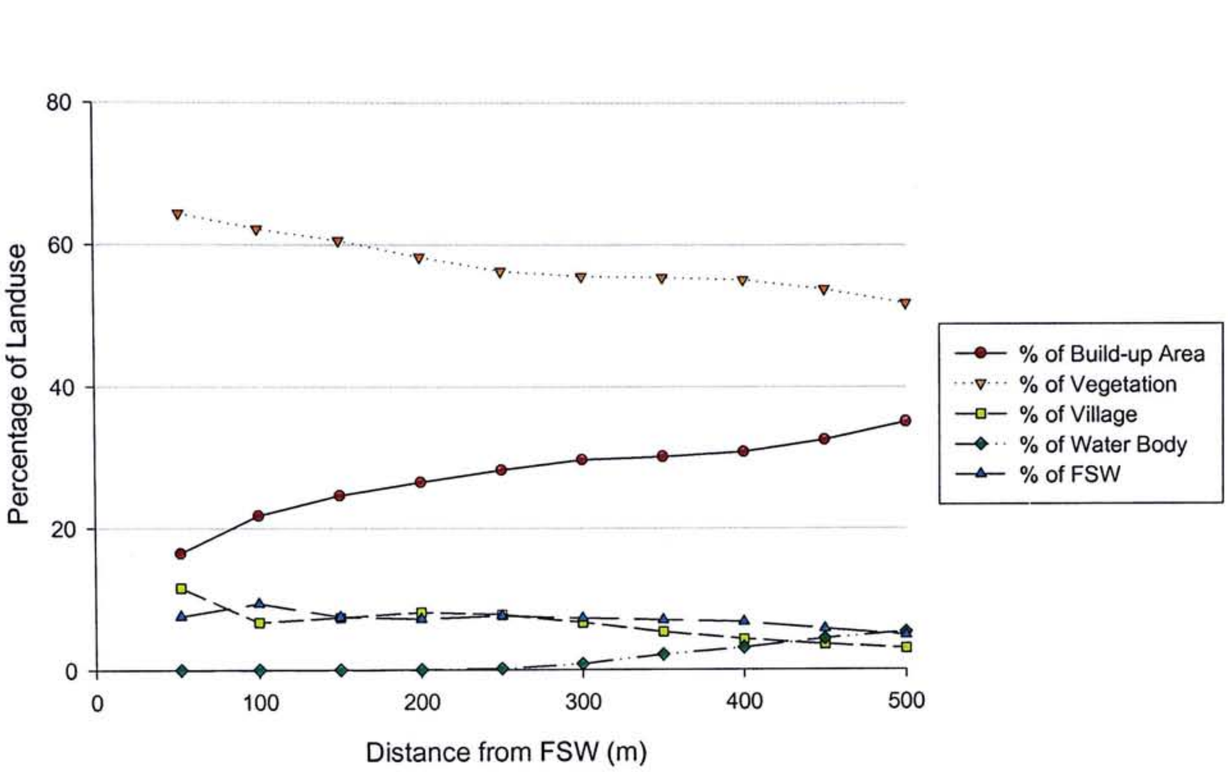


Figure A.27 Change of Percentage of Landuse in Puk Uk Tsuen FSW

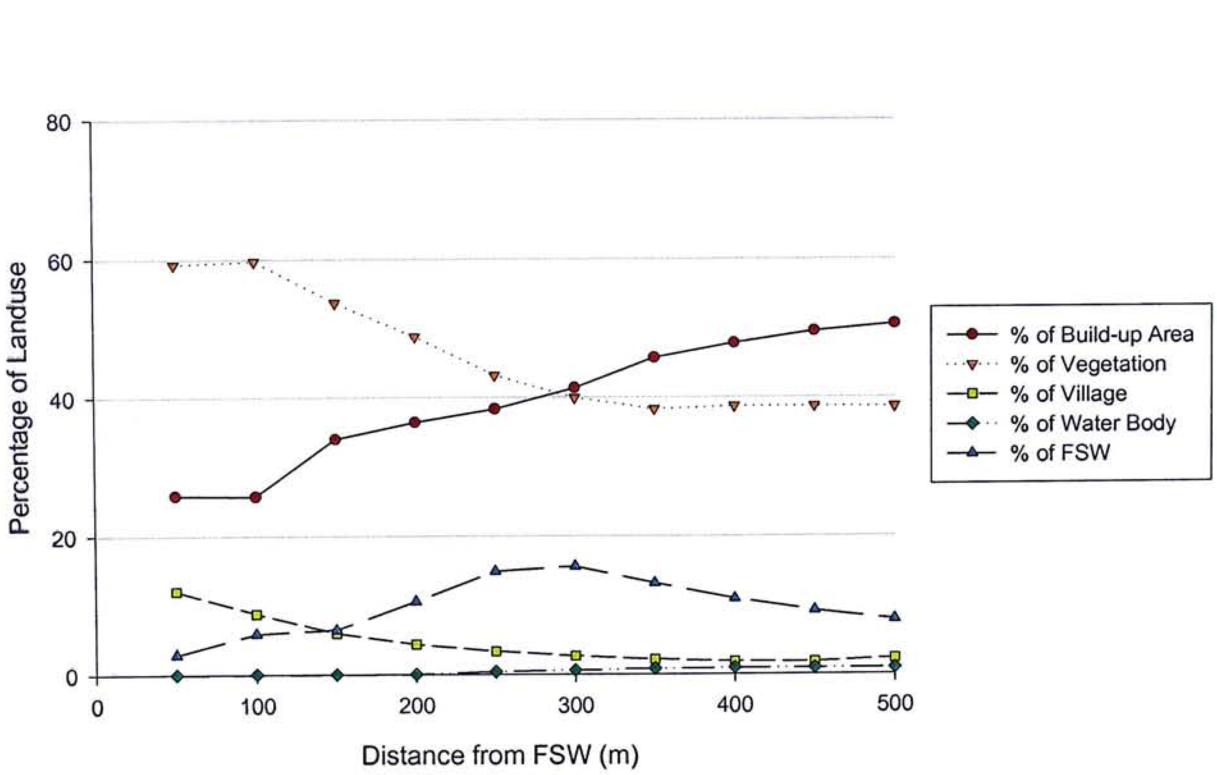


Figure A.28 Change of Percentage of Landuse in San Tong Po FSW

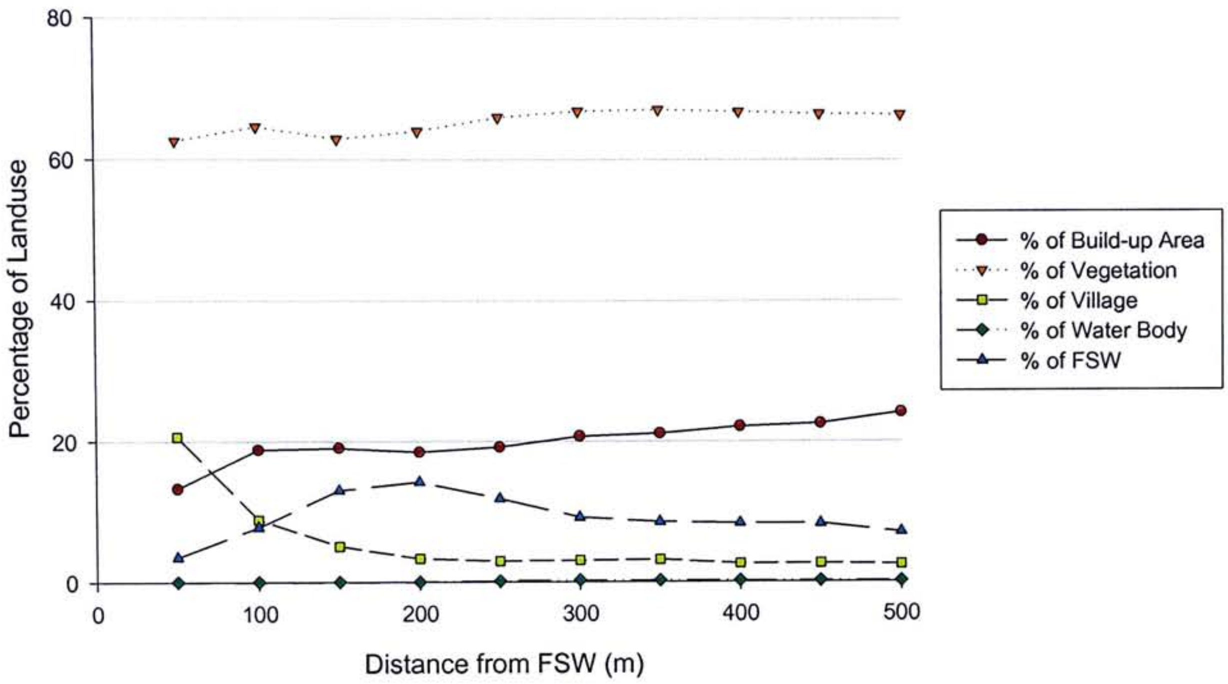


Figure A.29 Change of Percentage of Landuse in Sheung Shan Kai Wat FSW

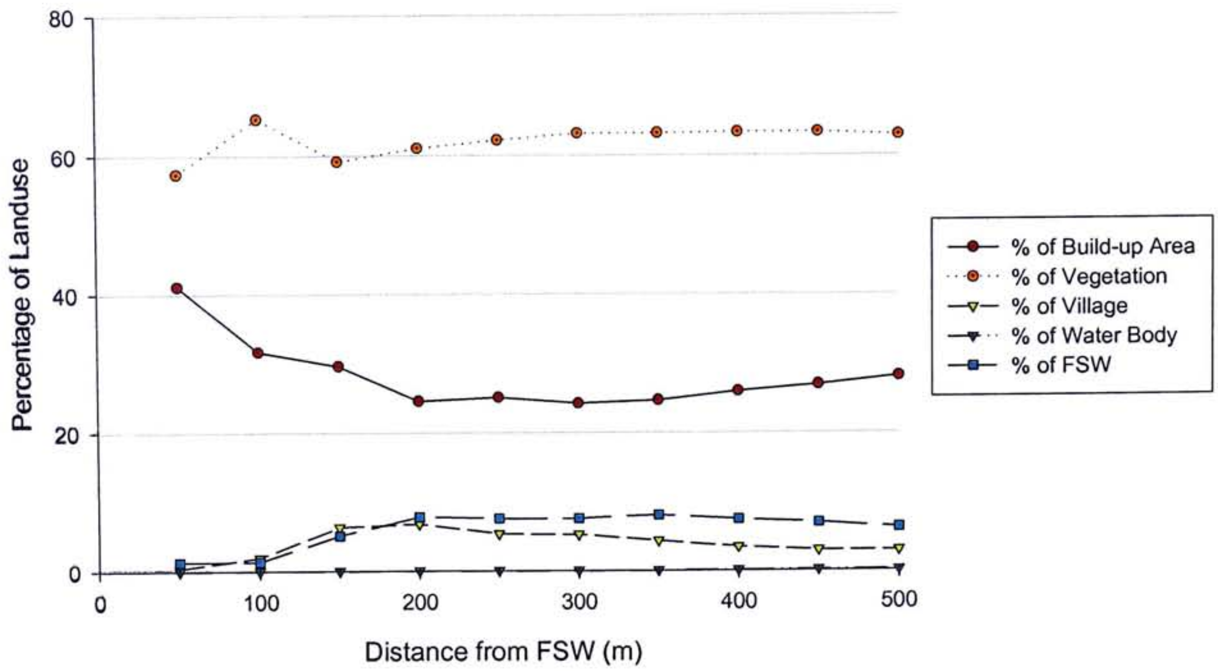


Figure A.30 Change of Percentage of Landuse in Sheung Shan Kai Wat 2 FSW

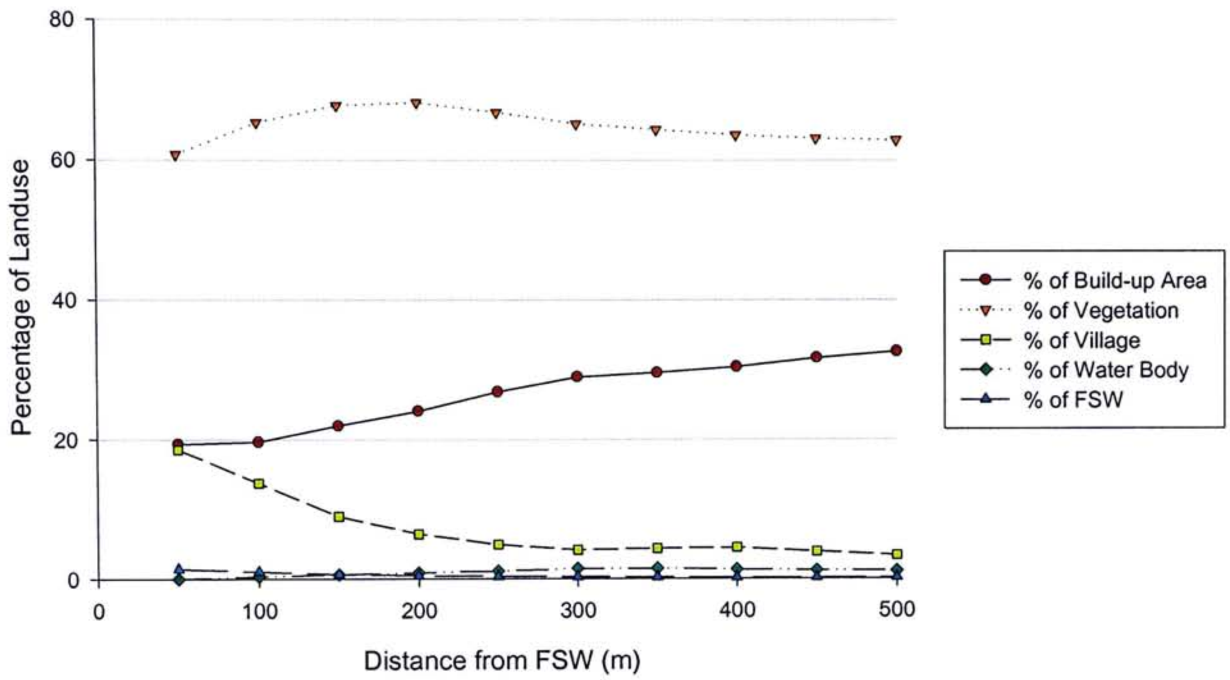


Figure A.31 Change of Percentage of Landuse in Siu Hang San Tsuen FSW

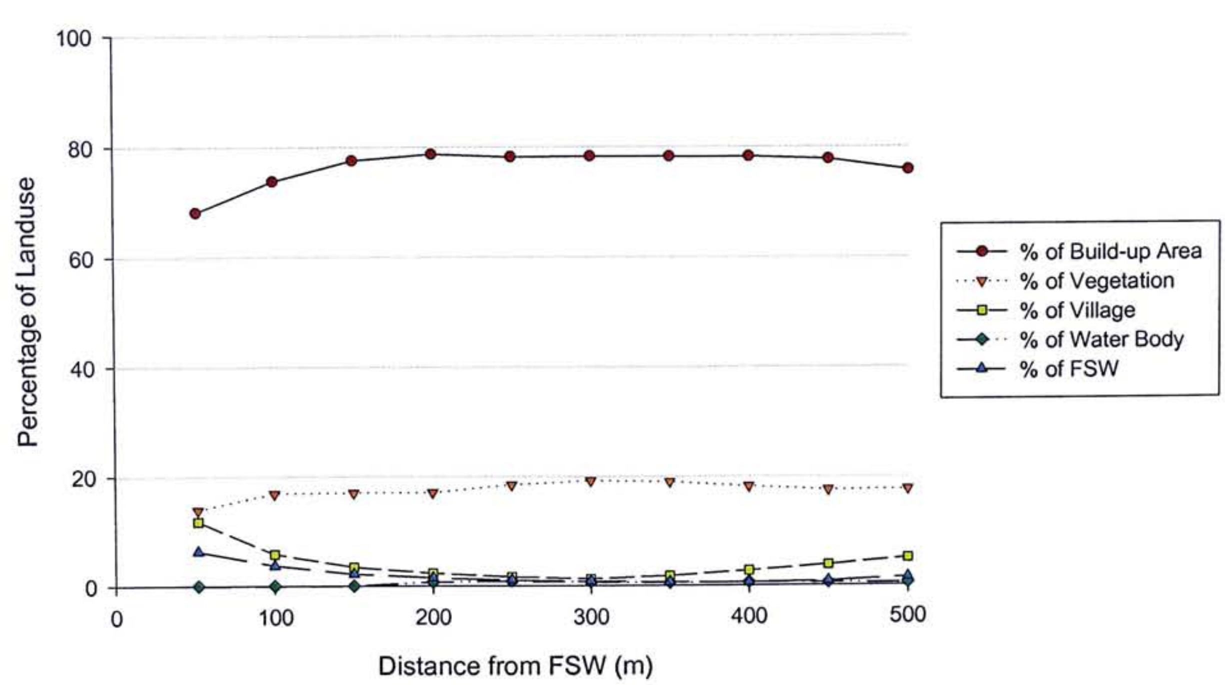


Figure A.32 Change of Percentage of Landuse in So Kwun Po FSW

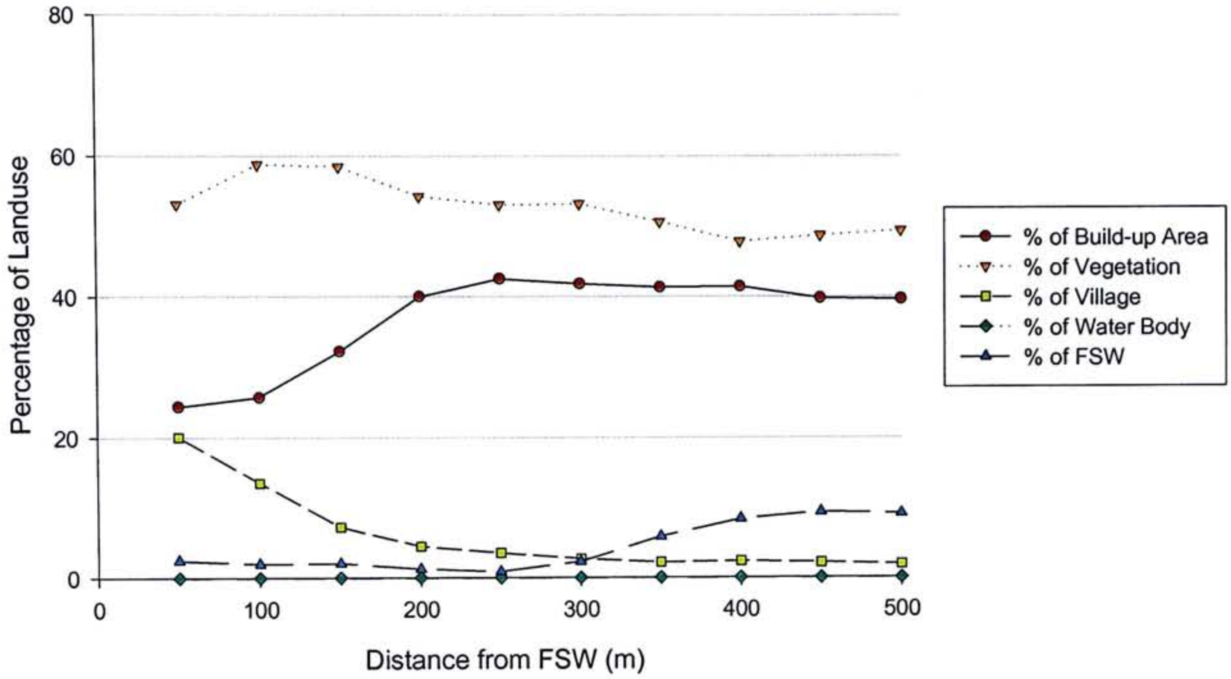


Figure A.33 Change of Percentage of Landuse in Tai Po Tin FSW

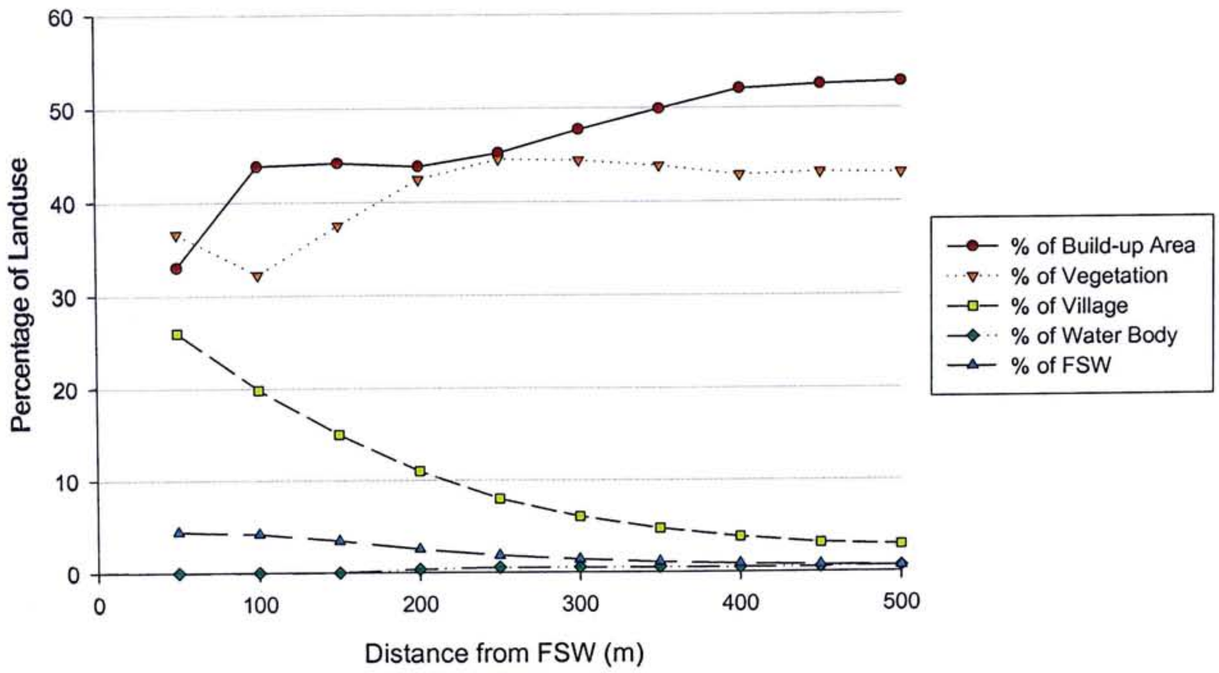


Figure A.34 Change of Percentage of Landuse in Tsung Pak Long FSW

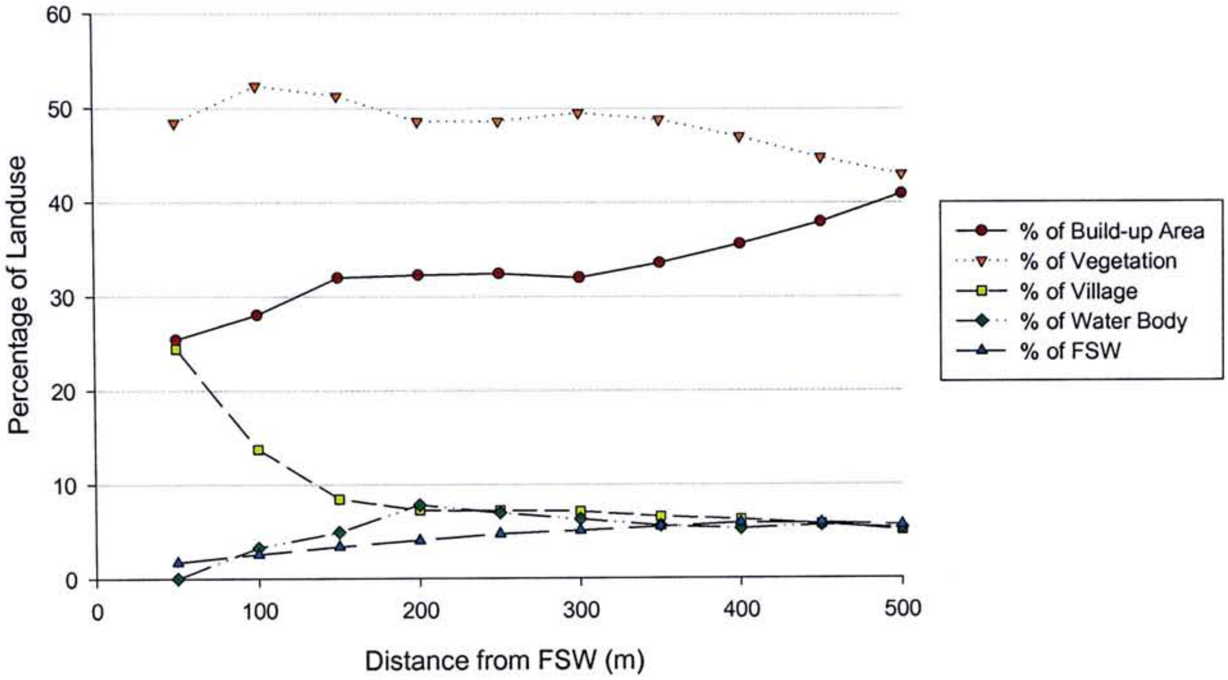


Figure A.35 Change of Percentage of Landuse in Tsung Yuen FSW

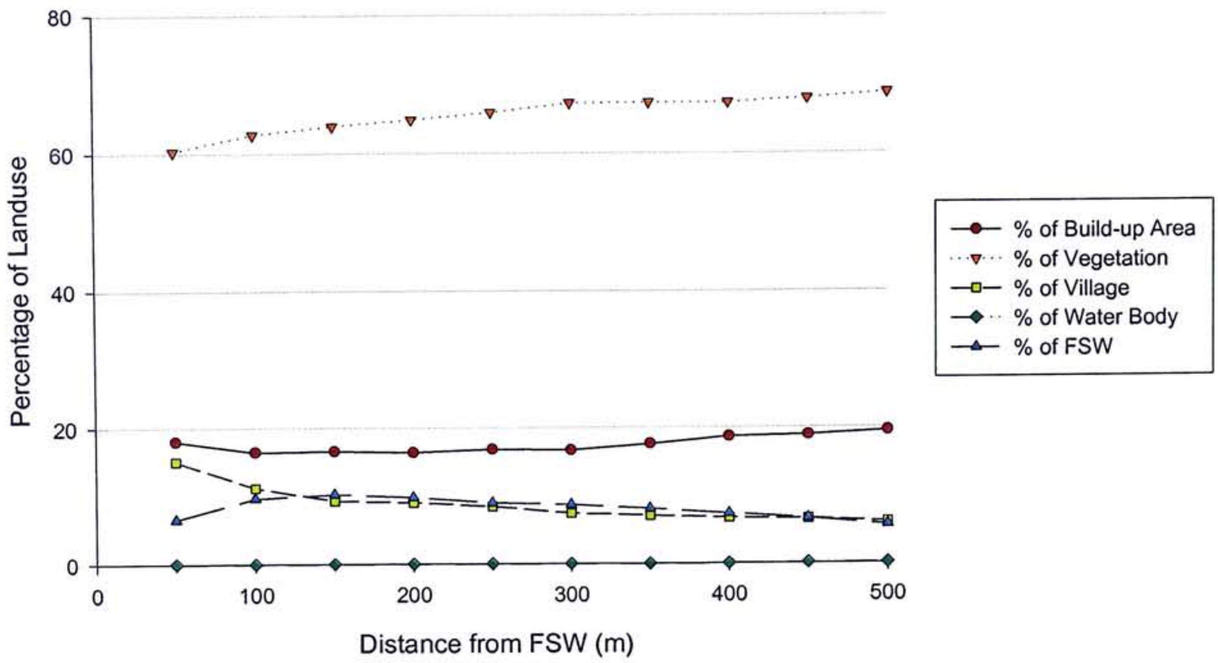


Figure A.36 Change of Percentage of Landuse in Tsz Tong Tsuen FSW

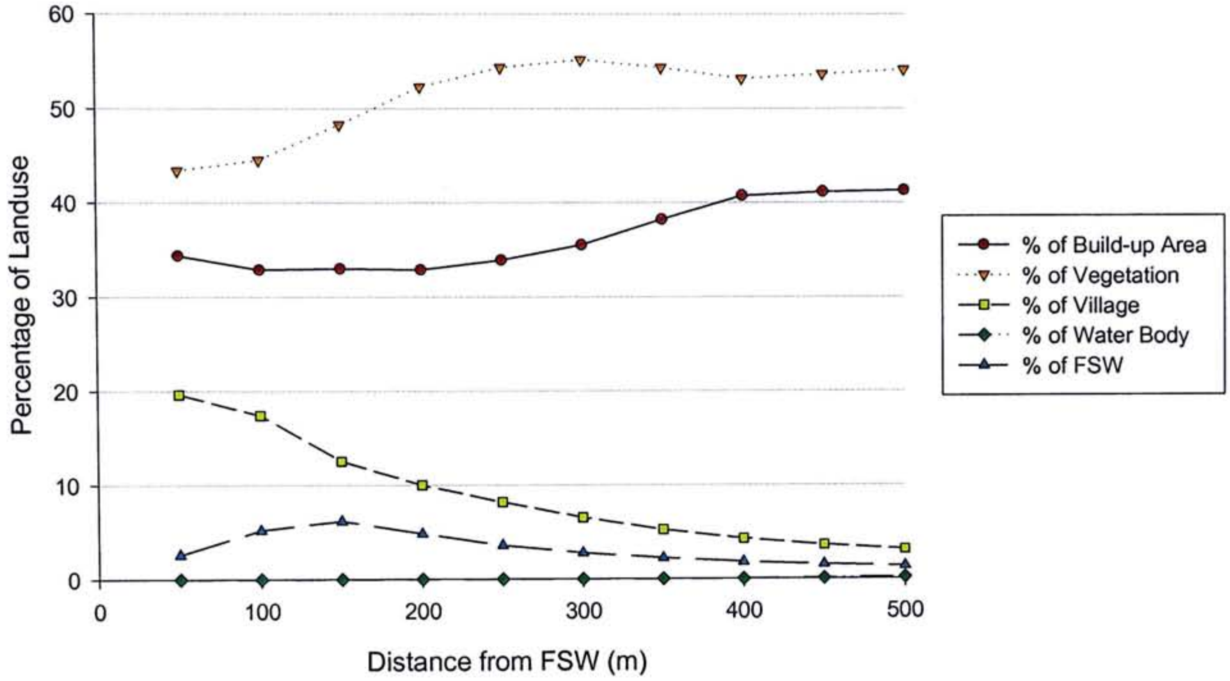


Figure A.37 Change of Percentage of Landuse in Wo Hop Shek FSW

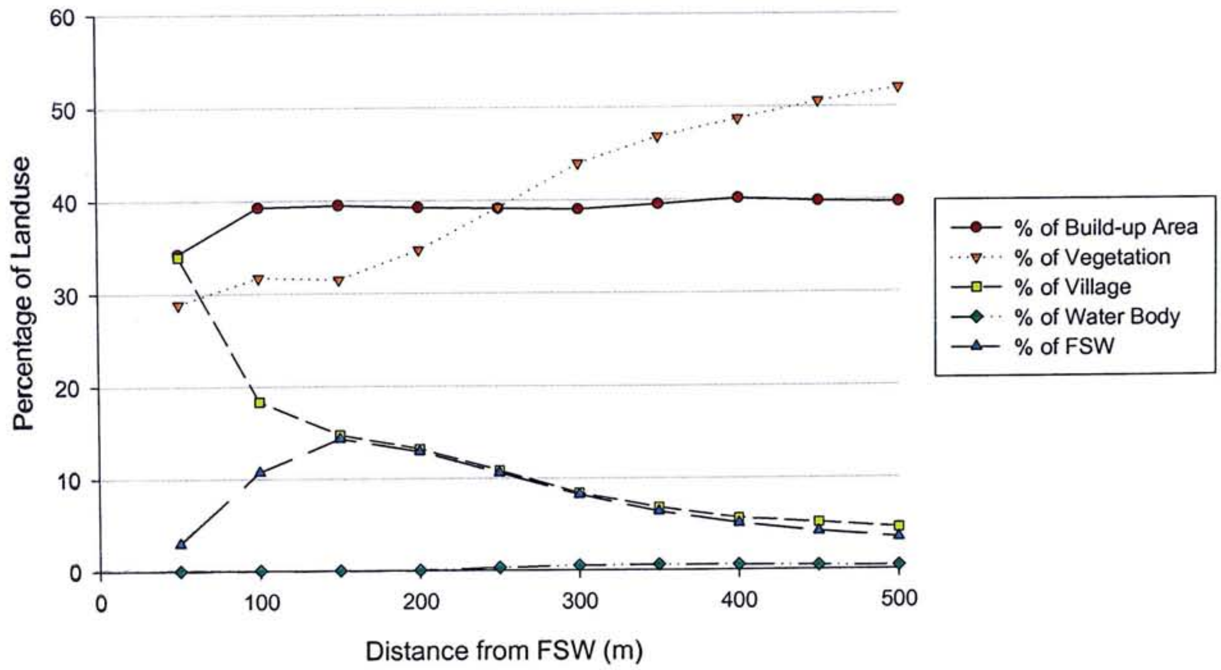


Figure A.38 Change of Percentage of Landuse in Wo Hop Shek 2 FSW

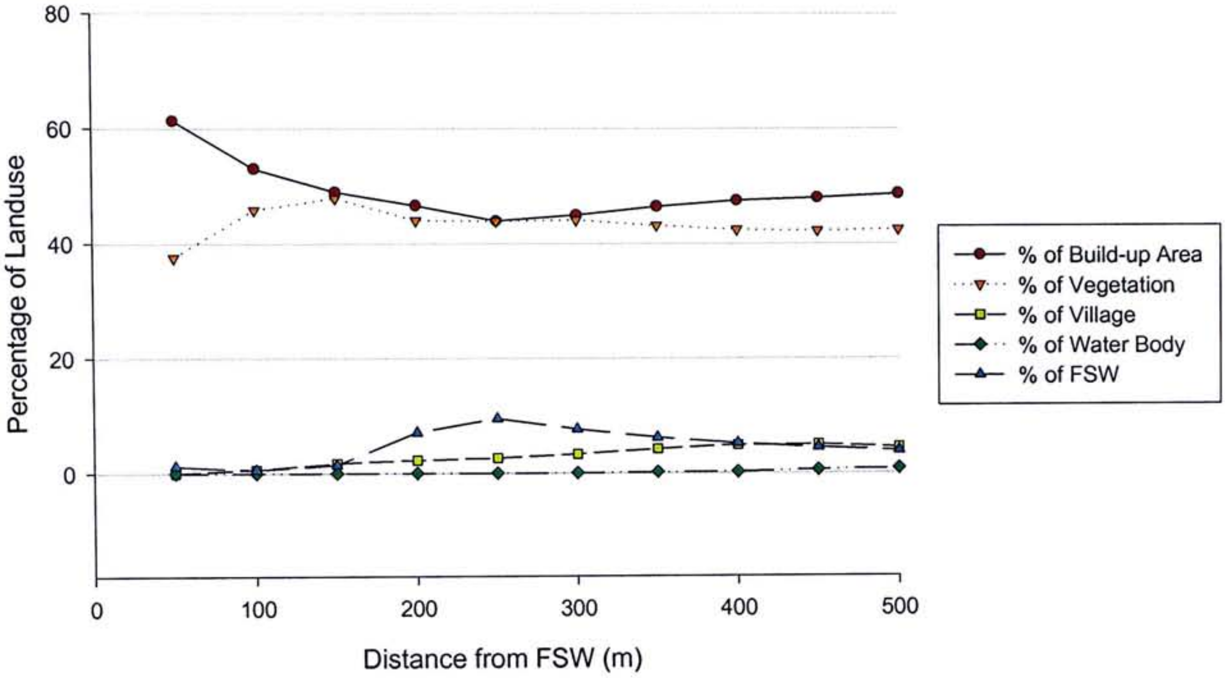


Figure A.39 Change of Percentage of Landuse near Woods 1

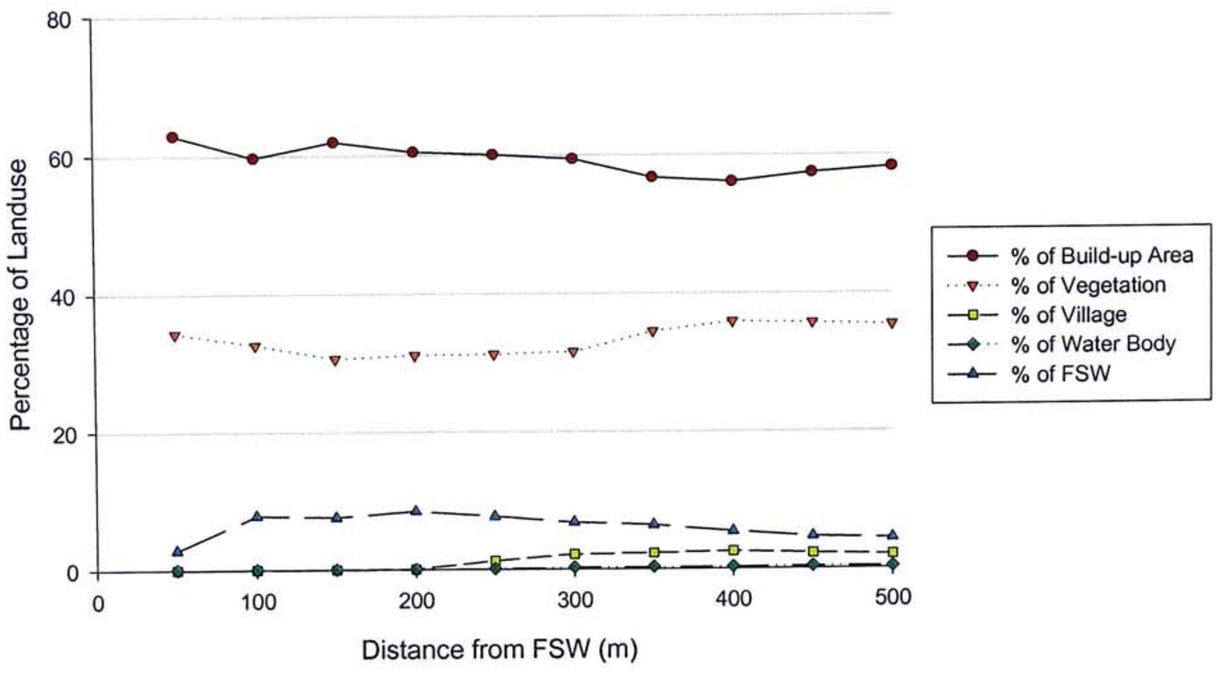


Figure A.40 Change of Percentage of Landuse near Woods 2

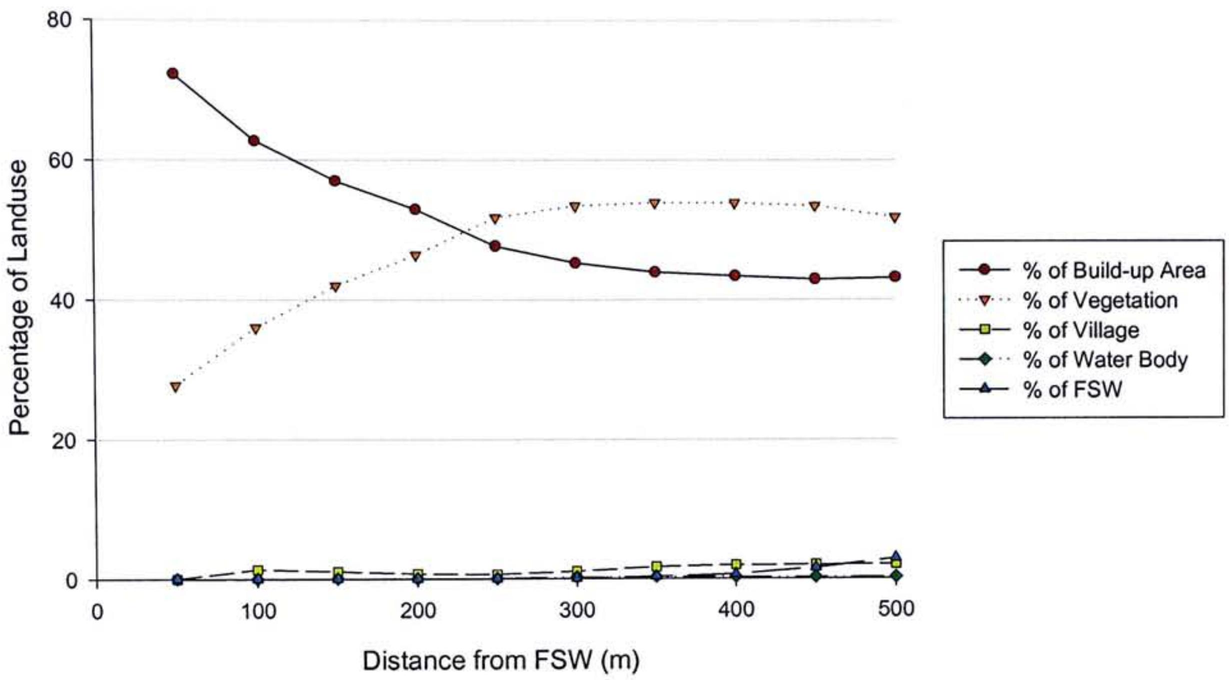


Figure A.41 Change of Percentage of Landuse near Woods 3

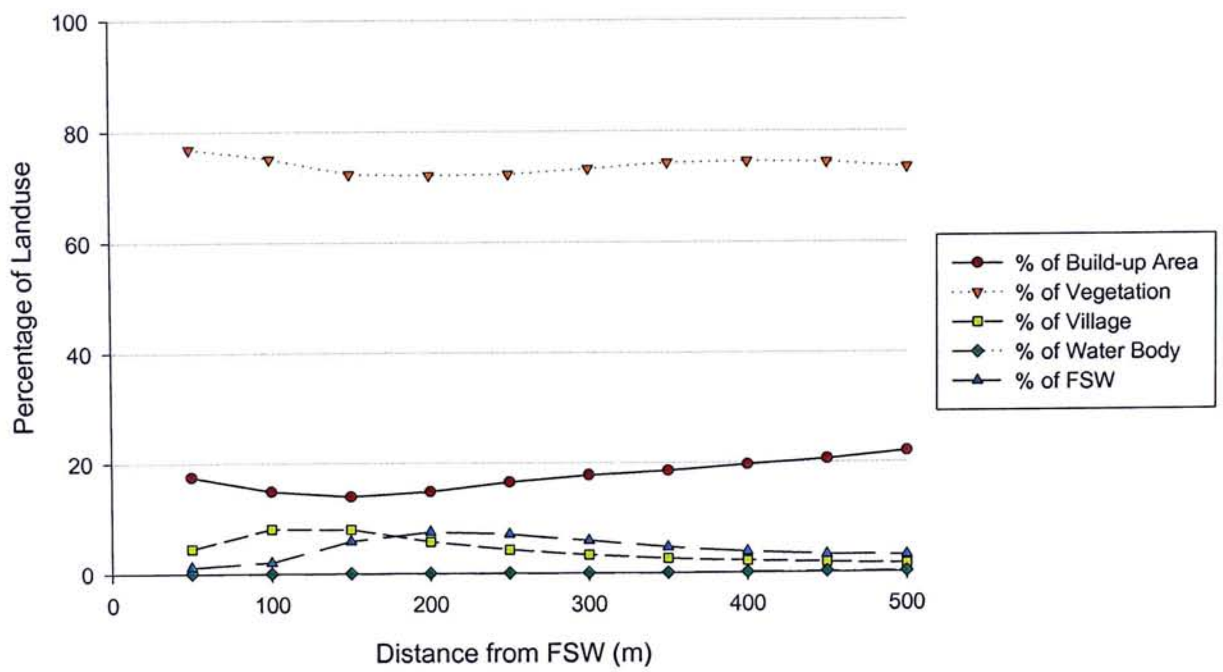


Figure A.42 Change of Percentage of Landuse near Woods 4

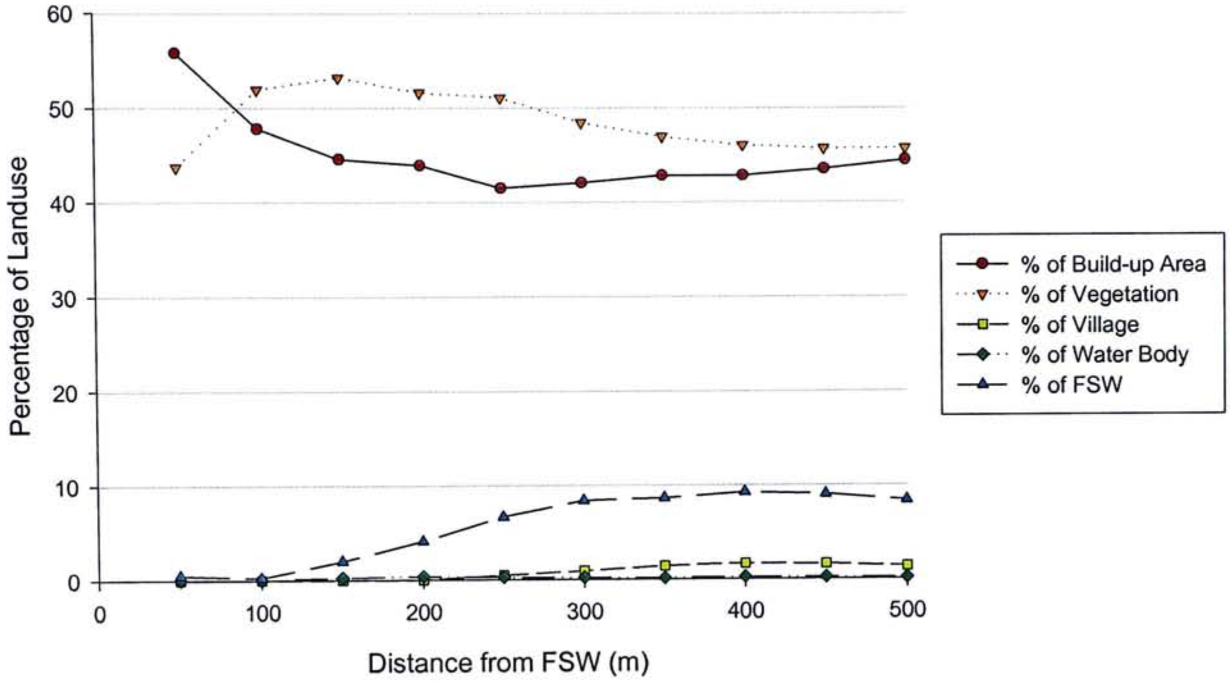


Figure A.43 Change of Percentage of Landuse near Woods 5

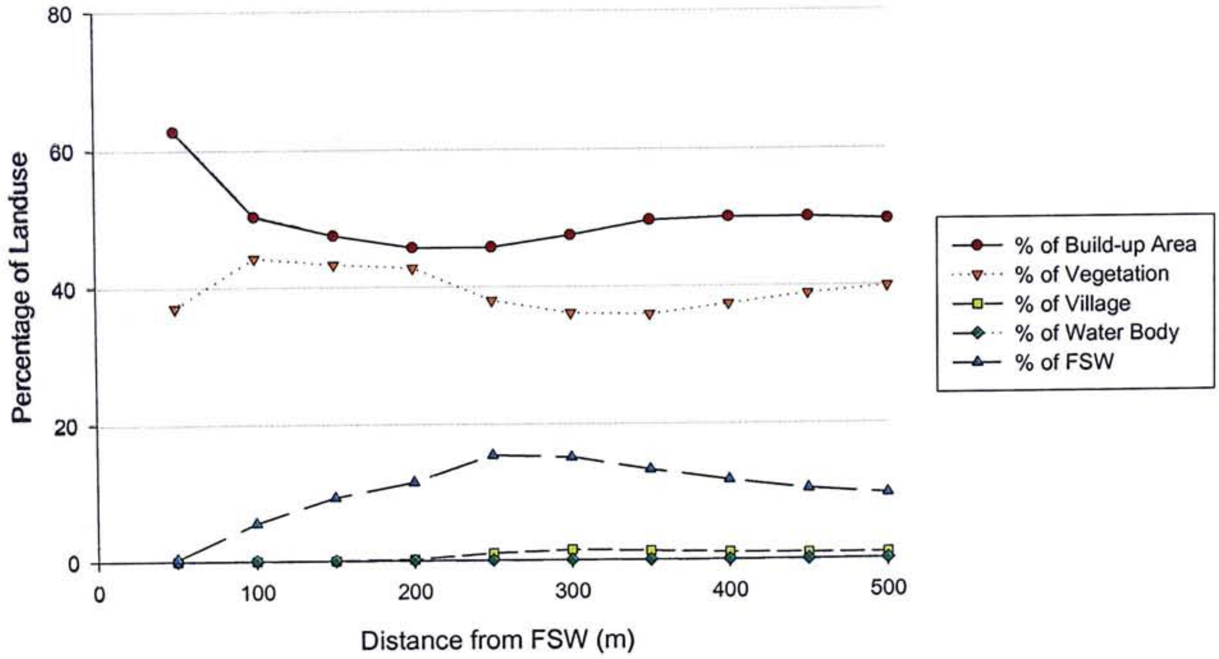


Figure A.44 Change of Percentage of Landuse near Woods 6

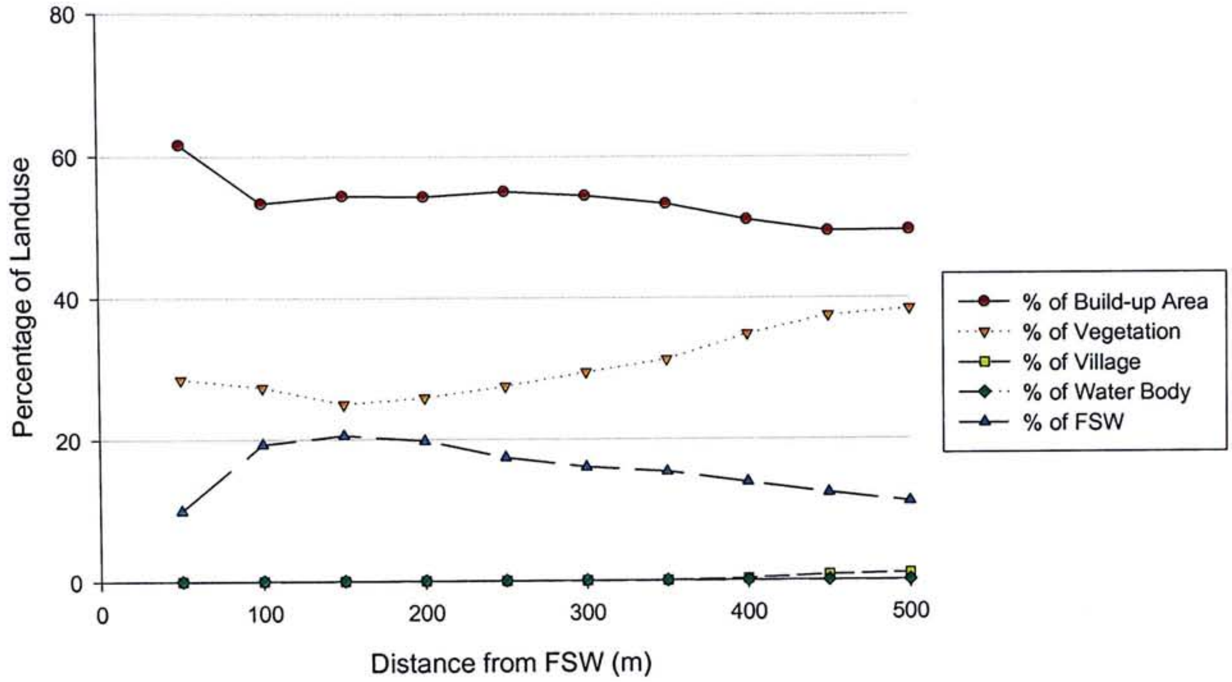


Figure A.45 Change of Percentage of Landuse near Woods 7

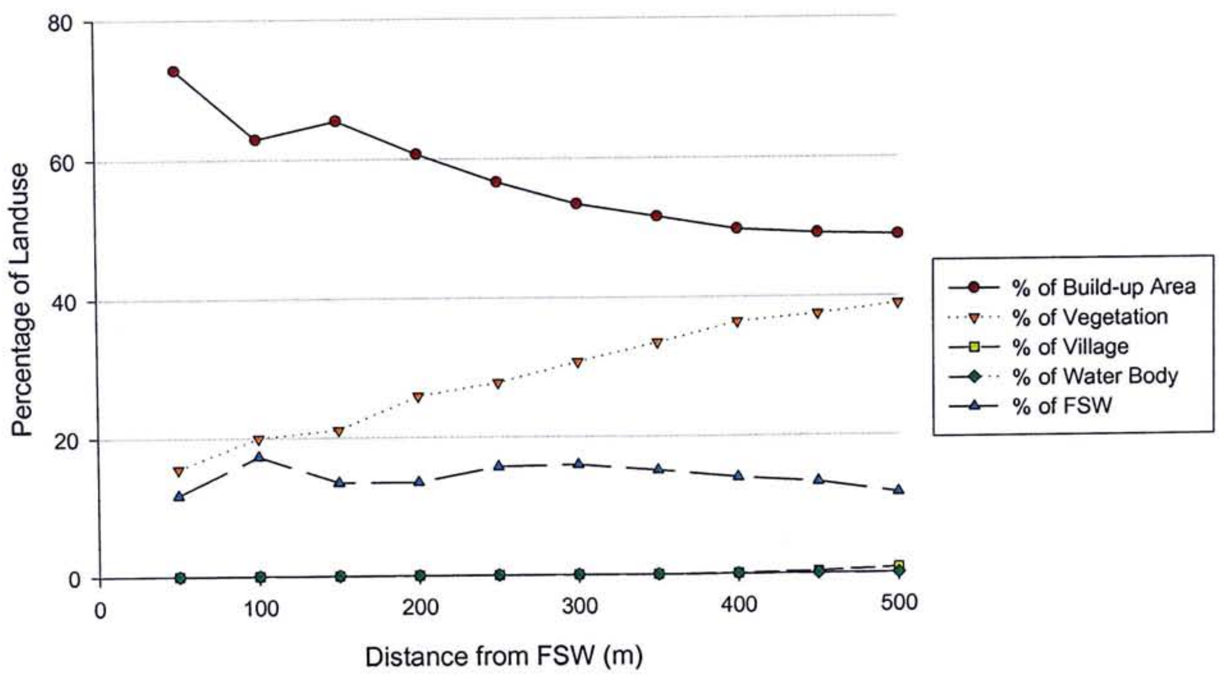


Figure A.46 Change of Percentage of Landuse near Woods 8

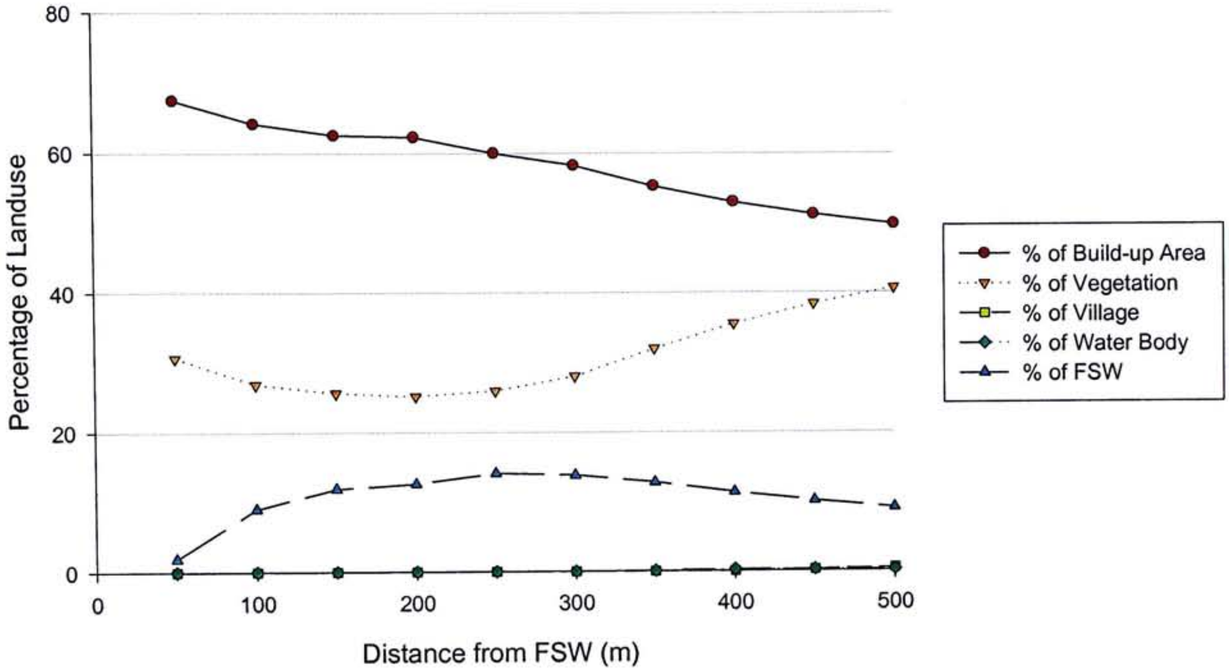


Figure A.47 Change of Percentage of Landuse near Woods 9

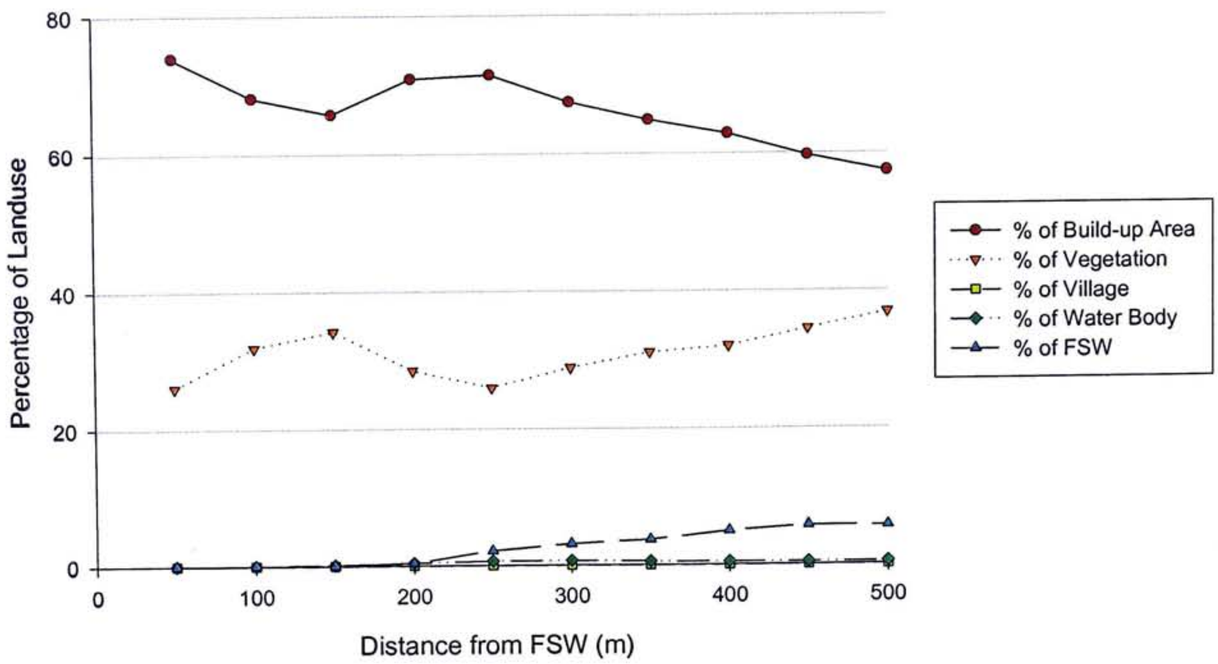


Figure A.48 Change of Percentage of Landuse near Woods 10

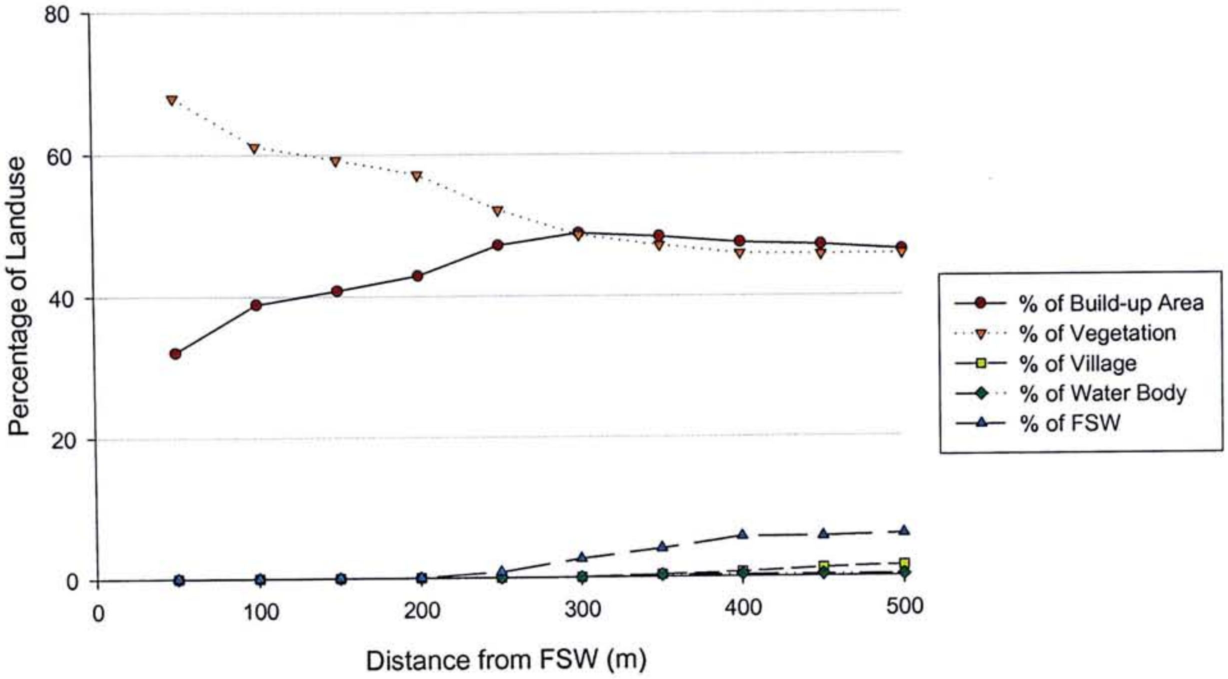


Figure A.49 Change of Percentage of Landuse near Woods 11

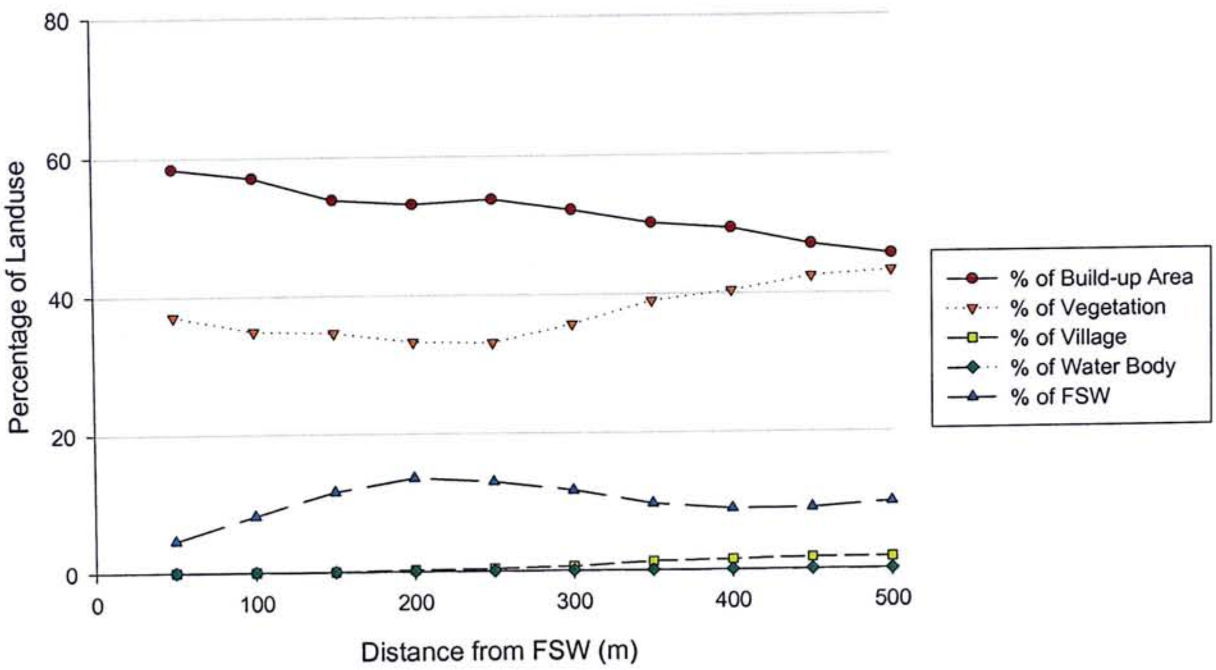


Figure A.50 Change of Percentage of Landuse near Woods 12

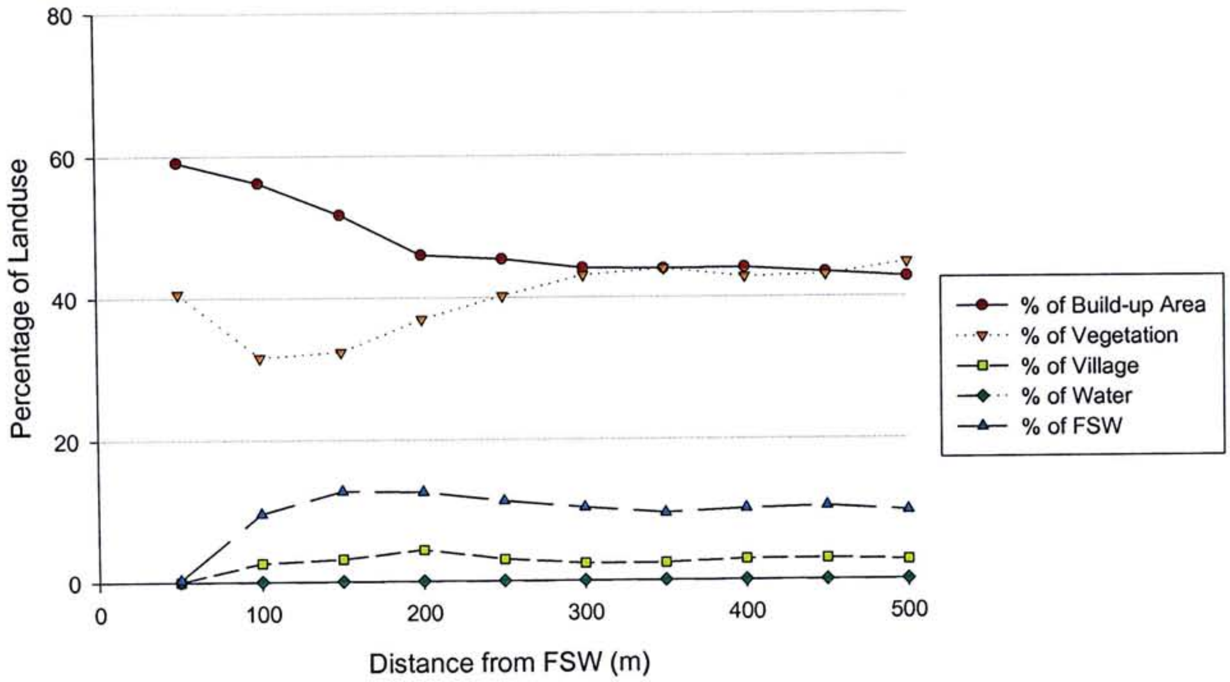


Figure A.51 Change of Percentage of Landuse near Woods 13

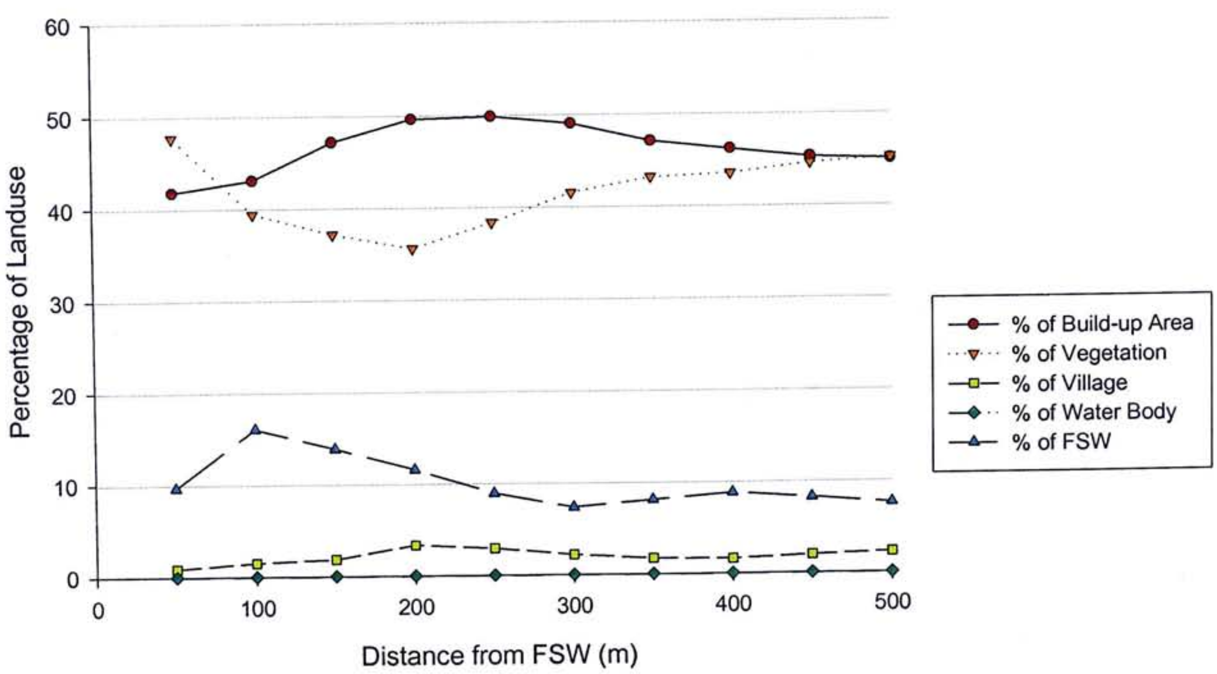


Figure A.52 Change of Percentage of Landuse near Woods 14

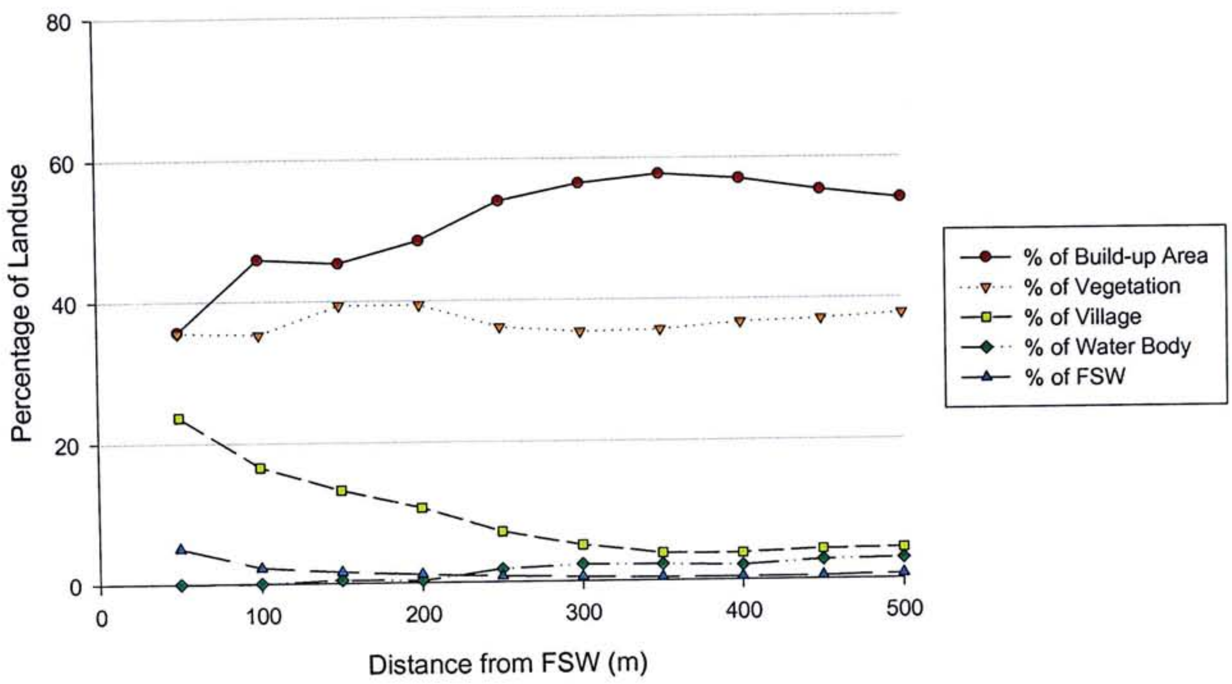


Figure A.53 Change of Percentage of Landuse in Yin Kong FSW